The
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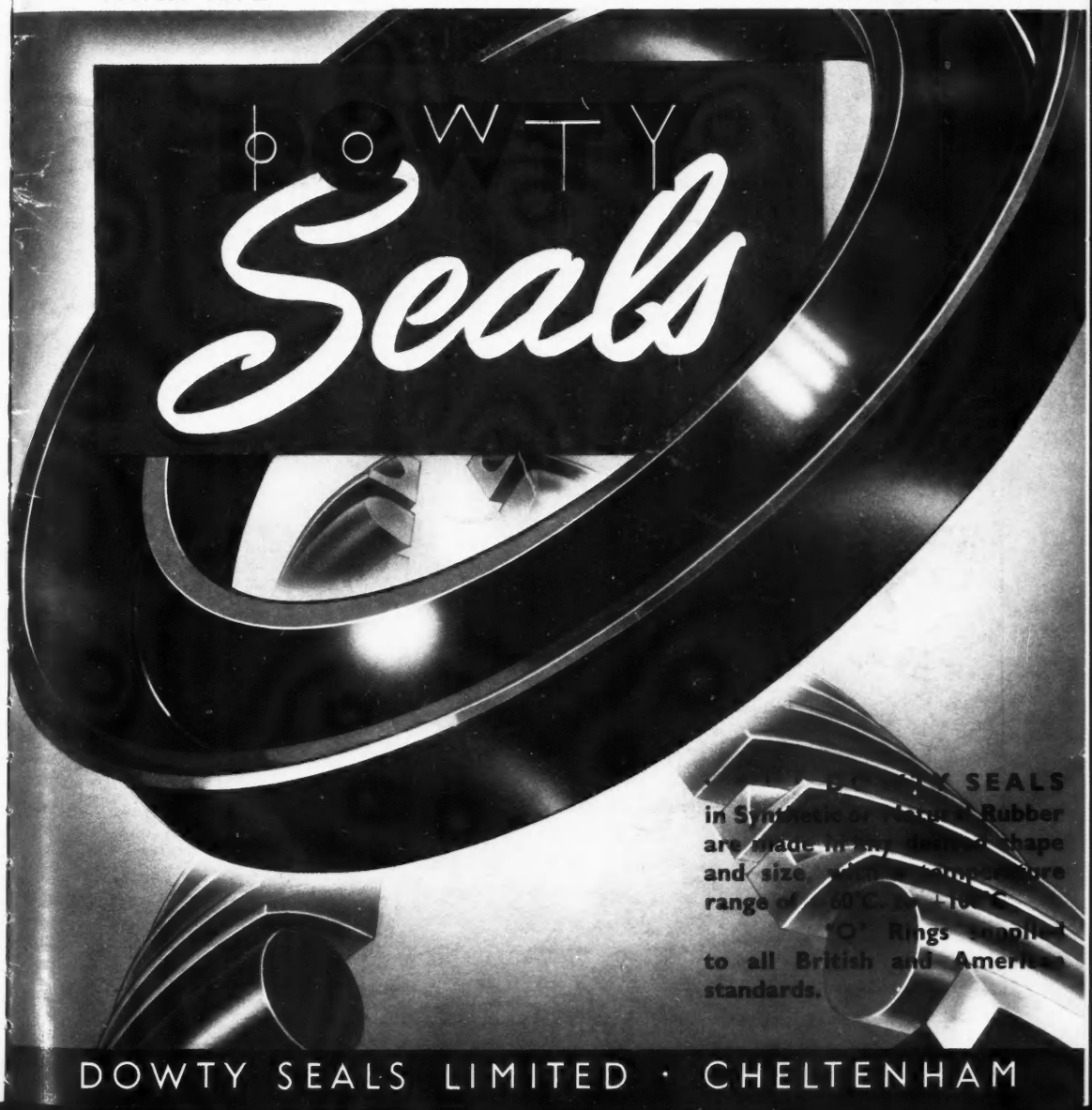


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# THE BLUE PAGES

## A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

### ● *BERYLLIUM PROGRESS*

It appears likely that in the field of powder metallurgy, beryllium may eventually find more applications because of the low density, good corrosion resistance and high relative strength of this metal. In fact, its strength/weight ratio is significantly superior to that of other materials such as aluminium, magnesium, titanium, or stainless steel. However, beryllium as now produced lacks ductility at room temperature. From a number of tests it has been concluded that beryllium powder can be compacted at room temperature without difficulty. To obtain a material of fairly high density, the beryllium compacts may be sintered in a high vacuum or in a protective atmosphere, such as argon, at temperatures below the melting point of the metal. Beryllium sintered in vacuo reveals measurable ductility, whereas argon-sintered beryllium compacts are brittle. Vacuum-sintered beryllium can be reduced nine per cent by cold rolling. It is most interesting to note that, according to a recent proposal, beryllium oxide may be used as a grinding and polishing medium in the field of hard metals and sintered metal oxides, especially sintered alumina. The report from which this information is derived enumerates several methods for the production of sintered beryllium oxide bodies for grinding applications.

### ● *APPLICATION OF SYNTHETIC LUBRICANTS*

Substantial savings in production costs and improved operation of mechanical equipment can be effected through the substitution of synthetic lubricants for petroleum products in certain industrial applications. In addition to their use as lubricants in the dairy, metal-working and other industries, synthetic fluids also find applications as anti-foaming agents, additions to detergents, etc. Where mass production methods involve the processing of a product at high temperatures, a lubrication problem frequently exists in the materials-handling equipment. This applies especially to the glass and ceramic industries, where polyalkylene glycol lubricants are finding a variety of uses, as, for instance, in the lubrication of wheel bearings on railcars carrying ceramic products through long tunnel kilns. The good extreme-pressure properties of these lubricants have been evident in certain metal-working operations, where their application results in prolonged tool life and better surface finish. At times, ease of removal or suitability for further processing without requiring cleaning of the product is the principal advantage of the synthetic lubricant. In lapping stainless steel threads with glass or diamond dust, superior finish has been obtained with polyglycol fluids. Rolling of nickel-silver, copper, sterling silver, brass and aluminium, has been accomplished with good finish and freedom from stains.

### ● *HYDROGEN REDUCTION OF IRON ORE*

Iron ore smelting today is completely dependent upon coal in the form of coke, the coke being used in the blast furnace as chemical reducing agent as well as fuel. Another reducing technique, which might be economically feasible, would be to use hydrogen as the reducing agent in place of the carbon, the iron ore being reduced to sponge iron. It is therefore interesting to note that recent laboratory tests are reported to have yielded promising results. The hydrogen method could not, of course, compete economically with the coke blast furnace process in steel-making centres built close to coal, but would be dependent upon the availability of cheap electric power. If, therefore, the hydrogen process could be based on atomic electricity, it would not only become economically feasible, but would also make the location problem immaterial, since no transport problems need be considered in the case of atomic power plants. It is reported that plans of this nature have been drawn up in the United States, where a prominent firm of metallurgical engineers has already designed an ore-reducing plant of this type. Considering that the coal production problem in this country is not likely to be solved for a good many years to come, a project of this nature would appear to be well worth investigating.

### ● *POWERFUL ELECTROMAGNET FOR RESEARCH*

A new design of electromagnet has been developed for research purposes where magnetic fields of very high flux density are required. This electromagnet is claimed by its makers to be the most powerful and versatile electromagnet that is commercially available. Although it weighs only about two tons, it is said to produce the same magnetic fields as other electromagnets weighing 15

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to 50 times as much. The operating characteristics of the electromagnet may be judged from the fact that a field strength of 35,000 gauss with a pole face diameter of 5¾ inches and an air gap of 2 inches is produced with a power rating of 125 kW. A field strength of 10,000 gauss with a pole face diameter of 11 inches and an air gap of 3 inches is produced with a power consumption of 20 kW. Provision is made for the easy interchange of pole pieces, the yoke halves sliding apart. For Zeeman effect studies parallel to the field, pole pieces with an axial hole are provided.

### ● *PRODUCING FLOW PATTERNS*

In view of the impossibility of predicting the fluid flow distribution in ducts and cavities, such as furnaces, by analytical treatment, it is usual to study the flow distribution on models built to scale. Several ingenious methods have been devised for various purposes, and in some of these, not only flow distribution but also heat transfer effects can be observed at the same time. In a recent investigation of this type, the flow distribution inside the model of an open hearth furnace was investigated, with flowing water used instead of the hot gases in an actual furnace. It is rather surprising that a flow of water renders a flow pattern which closely resembles that of a hot gas, but this is due to the fact that the buoyancy effects take place with a fraction of the velocity of the flowing medium. It has been found that with the use of a special oil burner, direct observation of flow distribution in a "hot" model can be easily carried out. This new technique, although still at an early stage of development, is stated to be extremely useful in enabling the effects of changes in design to be observed. By using high-temperature insulating brick which can be readily cut to the desired shapes, changes in design can be realised in the case of hot models much more rapidly than when using a three-dimensional water model.

### ● *ELECTRIC WEIGHING DEVICE*

For the rapid weighing of small weights, mechanical torsion balances have been in use for many years. A novel weighing device, in which the balancing torque is produced electrically, is claimed to constitute an important advance in weighing technique. Briefly, the mechanical part of the new device consists of a moving-coil system of the type used in d'Arsonval galvanometers. This system is equipped with a mirror and a weighbeam. The balancing torque is produced by an electric current passed through the moving coil. In the null position of the balance, a beam of light emitted from a stationary light source is reflected by the mirror upon a photocell which controls the grid potential of an electronic valve circuit. By moving the coil out of the null position by the weight of the body to be weighed, the light beam is partly deviated from the photocell so that the latter receives less light and, in consequence, an anode current is allowed to flow, which is passed through the movable coil, a shunt being provided for calibration and adjustment of the range of the balance. The anode current which establishes itself will then be a measure of the unknown weight, and the magnitude of the latter can thus be read off on a suitably calibrated dial. The balance is said to be extremely rapid in action. As it is the coil current itself which produces the balancing torque, the instrument is free from errors due to ageing of the valves, variations in supply voltage, etc. A typical instrument has eight measuring ranges covering weights from 1·5 to 300 milligrams.

### ● *TYRE TESTING BY ULTRASONICS*

The possibility of ascertaining the presence of cavities in materials by the application of ultrasonic vibrations is now being exploited for the testing of automobile tyres. This test enables the decision to be made whether or not a separation exists in a tyre which, owing to wear, needs rebuilding. In the apparatus developed for this purpose, the tyre is placed in a liquid solution, in which is also immersed a crystal transducer or vibrator for producing ultrasonic vibrations. The vibrations pass through the tyre and are picked up by a microphone opposite the transducer and inside the tyre. The intensity of the vibrations reaching the microphone is registered on a meter. When the carcass is sound and no internal separation is present, the meter reads full scale and a green light is shown. A separation between the transducer and the microphone reflects back a wave of decreased intensity to the microphone.

### ● *NOVEL TURBINE AND COMPRESSOR PRINCIPLE*

A French inventor reports favourable results of a first test made on a rotary machine designed to retain for a rotary engine the inherent advantages of the expansion or compression process as takes place in a piston engine. For the purpose of obtaining in a rotating machine the progressive volumetric increase or decrease in cylinder space which characterises the action of a reciprocating engine, the inventor employs two flat-faced discs revolving in opposite directions, with spiral pressure channels cut into the opposing faces, which are separated from each other by a small gap. The spiral channels or pressure grooves, which act as gas passages, increase in cross-sectional area in the same radial direction in both faces; also, as the grooves are inclined in different directions in the two surfaces, their point of intersection forms a cavity which moves radially during rotation of the discs. The gas admitted at the inlet point to such a cavity will therefore be compressed or expanded, according to whether the grooves are made to decrease or increase in cross-sectional

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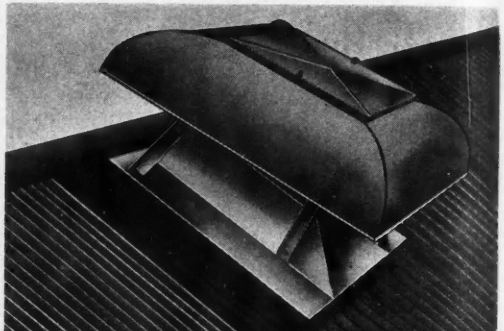

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area in the direction of radial gas travel. The operation of such a machine, therefore, resembles that of a multi-cylinder engine, each intersection representing one cylinder cavity. In view of the small size of the first experimental unit, it would be too early to pass judgment on the soundness of the principle, although the leakage through the air gap between the two discs would appear to be an inherent weakness of this design.

### ● *NEW GLASS FIBRE PAPER*

It appears that yet another important use has been discovered for glass fibre. According to a recent announcement made by the U.S. Defence Department, the U.S. Naval Research Laboratory has succeeded in developing a glass fibre filter paper which is five thousand times more effective than present commercially available filters. It is claimed that the paper made of glass fibre is one-twentieth the thickness of a human hair, is impervious to fungus, and can be made in conventional paper mills. Gas mask tests conducted in a smoke-filled room showed that only one particle of smoke in 100,000 passed through the filter, and this without any increase in the normal breathing resistance of the mask. No highly skilled or experienced personnel are needed for the production of the new paper, it is stated. Test runs at the National Bureau of Standards resulted in the production of such a paper of 0·01 inch thickness at a speed of 28 fpm. Full-scale mill runs have also been made. It is expected that the new paper will also find application in electrical apparatus, owing to its electrical insulating properties. As the new product is thinner and much more heat-resisting than the conventional paper used in electrical condensers, its use should enable the production of smaller condensers for application in electronic equipment.

### ● *STEEL HARDENING AT LOW TEMPERATURE*

Investigations at temperatures as low as that of liquid helium, i.e., —435° F, which is only six degrees above absolute zero, have shown that steel hardening takes place more completely at low temperature than at any other. The new studies also indicate that steel hardening is a co-operative shear-like sliding, in which many large groups of atoms move in unison and are thus transformed from austenite to martensite. In some types of steel, the amount of hardening, measured by the amount of martensite formed, was found to increase from very little at room temperature to nearly 100 per cent at the temperature of liquid helium. In other steels, hardening did not begin until the temperature dropped below —240° F. Hardening by cold-working the steel is also more effective at low temperatures. These recent findings constitute an important contribution to the theory of the mechanism of steel hardening. The new theory has made possible, for the first time, quantitative predictions of the behaviour of steel treated in specific processes and, therefore, provides a more scientific approach to future improvements in steel processing.

### ● *NOVEL PLASTIC SEALING COMPOUND*

A material which remains liquid as long as a stream of air bubbles through it, but which hardens in a few minutes when air is excluded, has been developed. This substance, which has been termed " anaerobic (i.e., non-airliving) permafil " is the latest in a series of compounds originally called " solventless varnishes," which harden by polymerization. When two metal strips are coated lightly with it and clamped together, the joint will support 10 pounds after 10 minutes, and 100 pounds after 20 hours. Still faster hardening can be obtained by heating up to 212° F. Certain metals, such as copper, iron, and silver solder, exert an accelerating action on the hardening process even at room temperature. One proposed use of anaerobic permafil is to eliminate the locknut needed to hold another nut tightly on a bolt. A few drops are placed on the threads of the bolt just before the nut is screwed on. The plastic hardens so tightly that very considerable force is required to remove the nut. Another use is for sealing threaded joints in pipes. Also, if painted on porous castings, the substance enters the pores and renders the casting airtight.

### ● *PRODUCTION OF SEMI-CONDUCTORS*

The number of applications of resistance units with negative temperature coefficient, or " thermistors," to electronic circuits has been steadily growing in recent years. These units are made of semi-conductive material classed midway between conductors and insulators, which show large changes in electrical resistance with temperature. Typical materials are metallic oxides, carbides, nitrides, sulphides, etc. Systematic investigations have revealed that in inorganic solids of a more or less polar type, as, for instance, oxides, a condition for electronic conductivity is that the lattice should contain ions derived from the same chemical element but of different valency in the same crystallographic position. A recent research report describes a new type of semiconductor in which this condition is realised by the introduction of a fraction of ions of deviating valency without the simultaneous formation of lattice defects as in non-stoichiometric compounds. This condition is produced by the incorporation in the lattice of foreign ions of such a charge that they balance the charge of the ions of deviating valency. This controlled valency principle is effective in numerous cases, and substances and the knowledge gained have already been used to produce a number of materials of specific properties used in thermistors.

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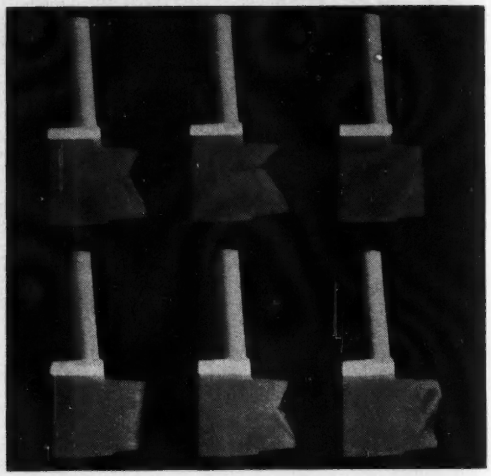

*Cast-steel gas turbine blades radiographed to show shrinkage. Taken on ILFORD Industrial X-ray film 'B' and reproduced by courtesy of "The Palmer X-ray Industrial Service," Penfold Street, London, N.W.8.*

Checking by radiography is an excellent way of spotting trouble before it becomes expensive. Castings with hidden flaws such as filamentary shrinkage can be weeded out before money is wasted on machining them and dangerous defects can be revealed in time to prevent serious trouble later.

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### ● *LOW-TEMPERATURE ENAMEL COATINGS*

An enamel coating process has been developed, in which the temperature required for firing the coated material is much lower than has hitherto been required in the usual sheet iron enamel processes. It is claimed that the new process permits the coating of very much lighter gauge sheet metal than has heretofore been possible. The actual method employed consists in firing the coated metal in an oxidising atmosphere at a temperature which is slightly higher than the fusing point of the glass or enamel employed. This temperature, however, is still below the critical point of steel, that is to say, below 750° C. Below this temperature, no physical changes take place in the steel, so that there is less danger of warpage, strain and softening of the steel. It is claimed that with the new process, No. 30 gauge steel sheet has been successfully coated without any warpage or strain occurring in the parent material. The glass or enamel coatings used for this purpose include molybdate of iron and/or copper, which cause the fused glass or porcelain to be bonded to the iron surface to which they have been applied. The bonding process is said to rest on the utilization of the phenomenon that the copper and iron atoms of the molybdate are bonded to the nascent iron oxide at the surface of the piece, while the molybdenum atoms are bonded to the glass of the vitreous coating. A series of glasses has been developed which can be bonded at temperatures ranging from 100 to 1320° F.

### ● *NEW METHOD OF UNIONMELT WELDING*

There are certain types of welding applications where shallow penetration of the weld bead is especially desirable. The production of composite structures, such as stainless-steelclad assemblies for the chemical industry is a typical example in this respect. The usual technique employed for this kind of work is to employ low speeds of travel and low welding currents with relatively high arc voltages. With this technique, dilution values as low as 20 per cent may be obtained in single layer deposits, that is, 20 per cent by volume of the fused metal consists of base material and the remaining 80 per cent is deposited rod metal. However, even this amount of intermixing with the base metal is often prohibitive. A new method is now available which drastically reduces the penetrating effect of the welding arc by employing two or more converging welding rods connected electrically in series. Under these conditions, the base material is electrically insulated from the power source, and the welding current flows from one rod through the welding zone back to the other rod. Each rod is independently fed by its own motor and voltage control system through insulated contact jaws, any of the commonly used types of submerged welding equipment being suitable. Either alternating current or direct current can be used, but alternating current is preferred when welding with rods of mild steel or stainless steel.

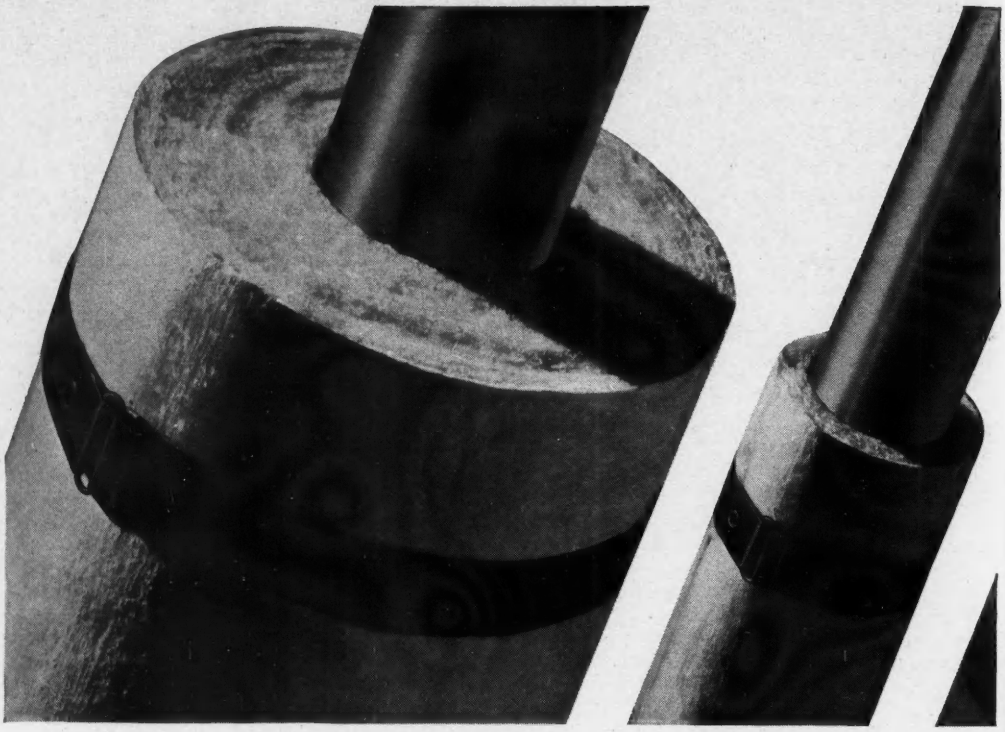
### ● *RESISTANCE WELDING UNDER WATER*

Probably one of the most interesting aspects of the development of techniques for the manufacture of combustion equipment for gas turbines is the application of resistance-welding processes to this class of sheet-metal work. From the resistance-welding aspect, the high electrical resistivities and low thermal conductivities of the high-temperature alloys used in this class of work are highly important insofar as they allow these alloys to be welded with less electrical energy than is required for mild steel. The high resistances give a greater heating effect for a given current, and the low thermal conductivities allow the heat thus generated to be retained more readily in the weld zone. The tendency to retain heat can influence the amount of distortion; however, advantage is taken of the corrosion resistance of these alloys, and distortion is kept down by welding under water. Thus, in stitch welding, a flow of water is directed over the electrodes and the work, the water flow taking away the heat after the weld is completed. Effective cooling is most important for seam welding, as the energy required to make a given joint is put into the work in a fraction of the time required for stitch welding, and distortion can be most serious, sometimes producing extensive shrinkage cracks on cooling. Welding under water jets has proved satisfactory, although a much greater flow of water is required than for stitch welding.

### ● *NOVEL ELECTRIC MOTOR*

A new type of induction motor has been placed on the market, which differs from the conventional types in that its armature remains stationary, with the cage revolving around it. The makers point out that this feature leads to a greatly simplified design and results in a highly compact machine. It is also claimed that by increasing the air gap by as much as 60 to 80 per cent as compared with conventional designs, a 30 per cent decrease in reactive current is obtained for equal magnetic field strength. The advantage of a revolving cage is also said to be reflected in a greatly increased cooling effect. It would appear that, for the present time, only one type of fractional horsepower size is being produced.

***For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.***



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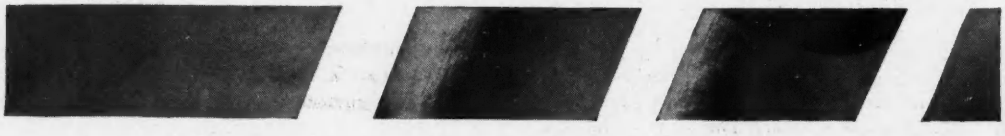

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VOL. XII. No. 2 FEBRUARY, 1951

# Rearmament and Productivity

It is unfortunate that so soon after a war that has plunged the whole world into difficulties from which it has only just begun to recover, the trend of present events compels us and indeed the whole Western World once again to devote our raw material and man-power resources to the task of providing adequate defence against any possible aggressor. We have no alternative but to accept the situation and support all efforts to implement the planned rearmament programme as the only means with any chance of success in averting a future war. It is, therefore, merely a question of how best to carry out this plan with the least possible detriment to the economic structure of the State and the well-being of the individual.

No one likes higher taxes, but if we are determined that this country shall be strong, we must be prepared to pay the cost of defence. We can pay the price by open inflation, we can pay the price by suppressed inflation and strict controls, or we can pay in high taxes, financial restrictions and Government economy.

This third way is in some respects the most difficult. It makes the costs of the programme clear and open. Therefore, it depends for its success upon public support ; it cannot be imposed or " slipped across." This approach requires that the Government take the responsibility for developing a programme that distributes the costs of military strength fairly. It requires that the Government set a standard for the behaviour of the private citizen by practising economy in its own expenditure. It requires that the public accept the costs, not only as they are meted out by tax laws and other financial regulations, but also by voluntary individual and group action. Success will be the result not of a handful of decisions made in Whitehall but of millions of private decisions to save, to work, to exercise restraint in pressing for higher prices and higher wage rates.

This is, nevertheless, the only acceptable course of action. It is fair and efficient. It would permit our growing military strength to be erected upon a solid base of growing economic strength. Beyond this, it is best for the very reason that makes it difficult, because it calls upon the responsible action of free citizens.

One aspect of this problem which cannot be overlooked, however, is that of increased production. Whatever the increased burden of taxes may be, no matter how far working time may be extended, the prime consideration should be increased productivity, which must come from the raising of industrial efficiency. This, to a very large extent, depends not only on the increased output from existing manufacturing potential, but also on greater capital investment to cope with the increased demands which will be made on our already overstrained resources.

Experience has shown that there are numerous ways in which industrial capacity can be raised; for example, improved materials-handling methods and equipment might well effect a considerable saving in the cost of handling as well as many hours of valuable labour which could be diverted to directly productive uses. Many of the machine tools at present in use in this country are obsolete, which is partly due to the fact that the best machine tools produced here have, in the past, been earmarked for export. Without attempting to enumerate the many possibilities which could be cited as solutions to this problem, the fact remains that modern technology can make a very important contribution. Success in raising output, of course, will rest not only with industry but also with the Government. It will be the Government's responsibility to apply any controls towards this end so as to render controls unnecessary at the earliest possible moment. As far as industry's function is concerned, it should co-operate in the development and application of labour-saving methods and equipment so as to ensure the raising of the British standard of living and the continuance of our free way of life.

The need for increased productivity in general is emphasised by the inevitable decline in engineering exports, which must be balanced by increased exports of non-essential goods to safeguard our economy. There can be no doubt that civilian demands must be restricted at first, but if we all pull our weight, with foresight and judicious planning we should be able to minimize the burden.

Last, but not least, an important contribution towards surmounting our present difficulties will be made by technicians who keep abreast of developments in methods and equipment taking place all over the world. It will, therefore, be the task of this journal, as always, to make such knowledge available for practical application.

FRANCE

# On the Mechanism of Metallic Fracture

By G. Homès and J. Gouzou. (From *Revue de Métallurgie*, Vol. 47, No. 9, September 1950, pp. 678-692, 36 illustrations.)

*No coherent theory of fracture can be established as long as the elementary mechanisms of crack formation are unknown. The present article describes preliminary, purely experimental, investigations into the mechanism of fracture in simple tension of small standard flat test specimens of zinc and mild steel. The specimens are stressed to fracture in a small tensometer apparatus with stress-strain recorder, and the phenomena observed by macro- and micro-photography and cinematography, as well as by X-ray diffraction patterns.*

While the processes of plastic deformation of metals are well known, research information on the actual mechanism of the final rupture is still lacking. Generally speaking, fracture occurs when, due to chemical, mechanical, electrical, or thermal action, the cohesive forces fail over a sufficiently large portion of the metallic cross-section. Many types of cohesive forces are known to exist, with energies varying in ratios of 100 to 1. Moreover, the external action may start structural changes, such as slip, according to whether the action is slow or rapid compared with the speed of formation of new interatomic links. Faults in the material and heterogeneities of composition and structure are probably even more important in starting a fracture than the stress distribution, because they locally affect the cohesive forces. It would be wrong, therefore, to distinguish between ductile and brittle metals: A metal is ductile only for a certain system of stressing and in a certain metallurgical state; in other circumstances, it may fracture in a brittle manner, i.e., without noticeable plastic deformation, as fatigue phenomena and the brittle fractures of welded constructions have shown.

The factors determining the mode of rupture are: the chemical, metallurgical and crystallographic state of the material, nature and amount of inclusions, temperature and speed of stressing. Mechanisms of fracture that could be expected to take place are: (1) slip implying change of shape and orientation of the crystals, and terminating in a tearing fracture of certain crystals after all possibilities of slip have been exhausted; (2) cleavage right across the crystal; (3) cracks formed inside the crystal progressing towards the boundary; (4) cracks formed at the boundary progressing inwards; (5) cleavage together with tearing of deformation bands that are bent locally; (6) separation at the grain boundaries; (7) twinning resulting in new cracks or tearing.

In order to observe the actual mechanisms and the influence of the various factors, standard flat tension test specimens of zinc, iron, mild steel, copper, and aluminium were tested to destruction; the results obtained with zinc and mild steel are summarised here,

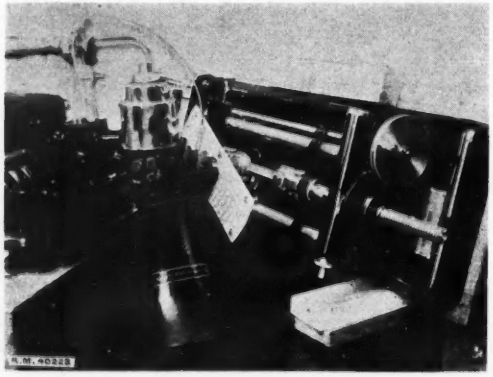


Fig. 1. **Arrangement of testing machine and X-ray unit for back-reflection photographs taken during stressing of the test material.**

and a suitable interpretation is proposed. Zinc has anisotropic crystals of hexagonal lattice structure with only three slip systems, mild steel a cubic lattice structure with more numerous slip systems, as also two different co-existing metallic phases. The specimens were first annealed to a state of complete recrystallisation with equi-axial grains. Grain sizes investigated especially were: about 0·2 in. to 0·004 in. diameter in zinc, 0·004 in. down to 0·0008 in. diameter in mild steel. The test pieces were polished and etched, then placed in a portable tensometer fixture (Fig. 1) with stress-strain recorder and a device for heating the specimen. The position of the tensometer was adjustable so that any point of the specimen could be brought under a microscope or an X-ray camera. Macroscopic and microscopic photographs and films as

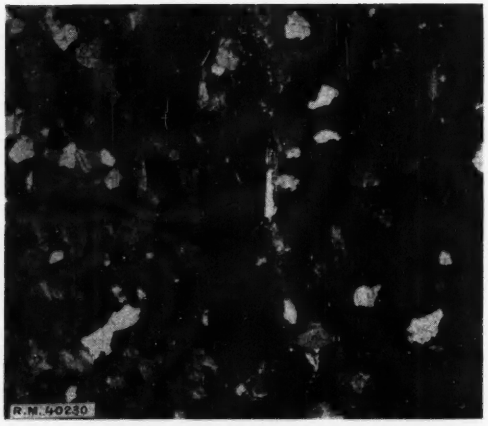


Fig. 2. **Fine-grained refined zinc fractured by sudden extension at room temperature. Macro-photograph taken at the moment of fracture (× 6).**

well as diffraction patterns could thus be taken of any one point throughout the test. The diffraction patterns served to indicate the crystal lattice distortions characteristic of work hardening as also the first traces of recrystallisation during test.

## TESTS ON ZINC

### A. Refined Zinc Fractured at Room Temperature.

Deformation bands are rarely seen. In a *fine-grained material under slow loading* (one hour to fracture), the grain contours are progressively distorted and the crystals rotate slightly. A certain stress relief is observed at a moment when numerous transcrystalline cracks appear. These " premature cracks " are quite separate from the final cleavage. Just before final fracture, certain cracks join up by a very localised grain boundary separation around grains averse to transcrystalline cracking. The final fracture then has a mixed aspect, but transcrystalline cleavage predominates. The X-ray back-reflection patterns indicate that the specimen is slightly and uniformly cold worked. *In fine-grained materials under rapid loading* (a few seconds

to fracture), the formation of the final cleavage is similar (Fig. 2), but cold work, still slight, is now localised in the region of final fracture. *In a coarse-grained material under slow loading*, the distortions and rotations of crystals are very much reduced. Final fracture still evolves in the same manner; transcrystalline cleavage predominates. A slight uniform cold work is again noticeable. Fig. 3 shows schematically the mechanism observed. *In coarse-grained materials under sudden loading*, the fracture is entirely transcrystalline (Fig. 4). Cold work, now non-uniform, remains localised in the region of fracture.

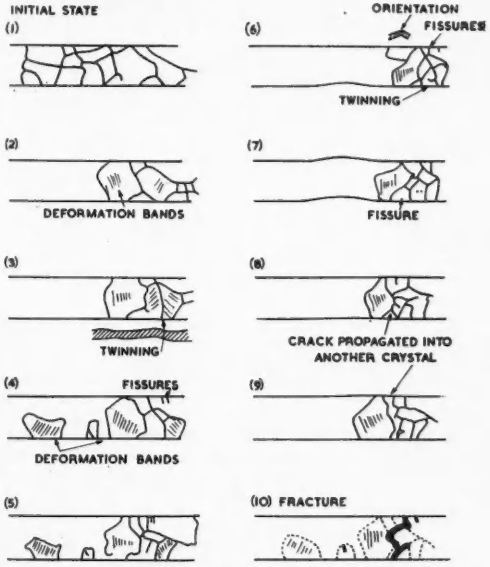



**Fig. 3. Schematic illustration of successive phases in the fracture of coarse-grained refined zinc by slow extension at room temperature.**

Thus, slip is rare, boundary separation and grain rotation are insignificant, if they occur at all; cleavage alone is decisive. The fracture is transcrystalline or mixed, and cold work slight. Under rapid loading, only the zone of fracture shows traces of cold work.

**Fig. 4. Macro-photograph of the fracture of coarse-grained refined zinc broken by sudden extension at room temperature (× 5).**

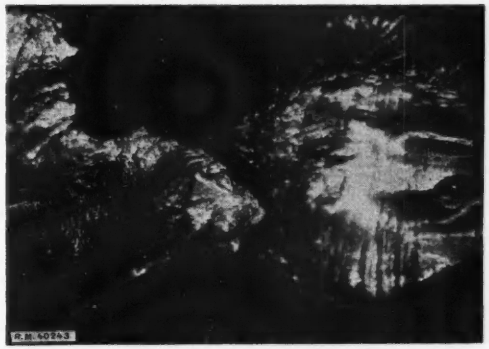


**Fig. 5. Fracture of coarse-grained refined zinc by slow extension at 300° C. Macro-photograph showing typical tearing fracture after slip (× 3·5).**

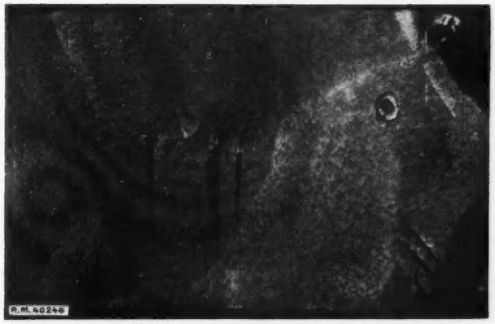


**Fig. 6. Fracture of coarse-grained commercial zinc by slow extension at room temperature. Macro-photograph of metal immediately before final fracture, showing multiple cracks in various regions (× 3·5).**

B. Refined Zinc Fractured at Elevated Temperatures.

No boundary separation or " premature cracks " were ever observed. At temperatures up to 100° C, the mechanism of fracture is still dominated by cleavage, but above 200° C, slip becomes increasingly important. At 200° C, slip and cleavage occur simultaneously; the fracture is mixed, and at certain points deformation bands are seen to tear apart after extensive parallel slip. At 300° C, failure takes place by slip only, and fracture occurs by tearing after severe parallel slip (Fig. 5). Cold work remains slight throughout and, above 200° C, a partial recrystallisation during test can be observed. Intercrystalline cohesion remains excellent throughout all tests. The mechanism of slip, " frozen " in tests on cold material, thus assumes growing proportions with increasing temperatures and finally determines the rupture.

C. Commercial Zinc Fractured at Room Temperature.

The impurities were, for the greatest part, well distributed within the grains; only a small proportion was concentrated at the boundaries. Fracture is purely transcrystalline, i.e., caused by cleavage. Premature cracks are frequent (Fig. 6). Slip thus seems to be impeded by the impurities, although the very existence of premature cracks, as also the fact that they open out during test, indicates that some crystals must undergo slip. Only slip of neighbouring crystals can so reduce the deleterious stress-concentration effect of premature cracks that they do not propagate to final fracture. Cold work is nil, or very slight and non-uniform.

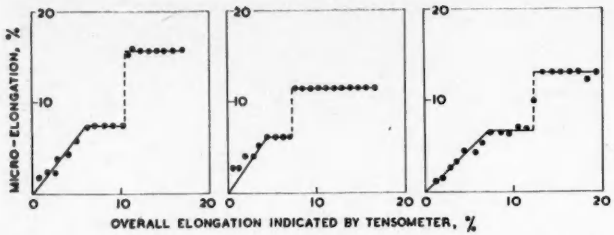



Fig. 7. **Tensile tests on mild steel of 0·004 in. grain size. Micro-elongation observed outside the zone of necking.**

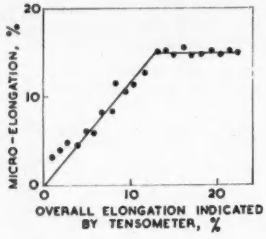
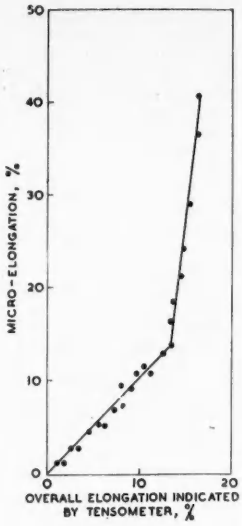



Fig. 8 (right). **Tensile test on mild steel of 0·004 in. grain size. Micro-elongation observed inside the zone of necking.**

Fig. 9 (left). **Tensile test on mild steel of 0·0008 in. grain size. Micro-elongation observed outside the zone of necking.**




## TESTS ON MILD STEEL, FIRST RESULTS

### A. The Local Plastic Deformation.

Because of the great number of possible slip systems, the rupture of mild steel is preceded by extensive plastic deformation; the tests were therefore extended to cover the micro-phenomena of this deformation. On test specimens of 0·14 per cent C-steel and 1 in. test length, specially selected regions of about 0·016 in. by 0·012 in. were observed throughout the test by micro-cinematography with 130 dia. magnification. A certain distance scale of the order of 0·01 to 0·012 in. was adopted for the measurement of the local extension within the region under observation. With an average grain diameter of 0·004 in., this scale unit would span a few grains only. The observed region is thus very small as compared with the overall dimensions of the test piece, and since its position must be arbitrarily chosen at the start of the test, it will often be found outside the zone of local restriction (necking) of the tensile test. In fact, the micro-region of three test specimens was situated outside the zone of necking, whilst, on a fourth test piece, it was inside that zone. Phenomena observed outside differ characteristically from those observed inside the zone of necking.

Although the movement of the tensometer was quite uniform, the micro-elongation observed in a region *outside the zone of necking* was found to be irregular. If this micro-elongation is plotted as a function of the overall elongation indicated by the tensometer (Fig. 7 are typical graphs), three stages of plastic deformation become evident:—(1) the micro-elongation increases approximately proportionally with the overall elongation, and a 45 deg. line is seen on the graphs; (2) the micro-deformation is arrested at a certain level and remains stationary in spite of increasing overall extension; (3) a sudden jump leads to a second, higher, level of plastic micro-deformation which again remains constant as the whole specimen is further extended. The jump coincides with the sudden appearance of deformation bands right throughout certain crystals of the micro-region (Fig. 11).

A check test on fine-grained (0·0008 in. grain diameter) 0·11 per cent C-steel resulted in a rather different graph showing only two stages of micro-deformation: the proportional stage and the definite

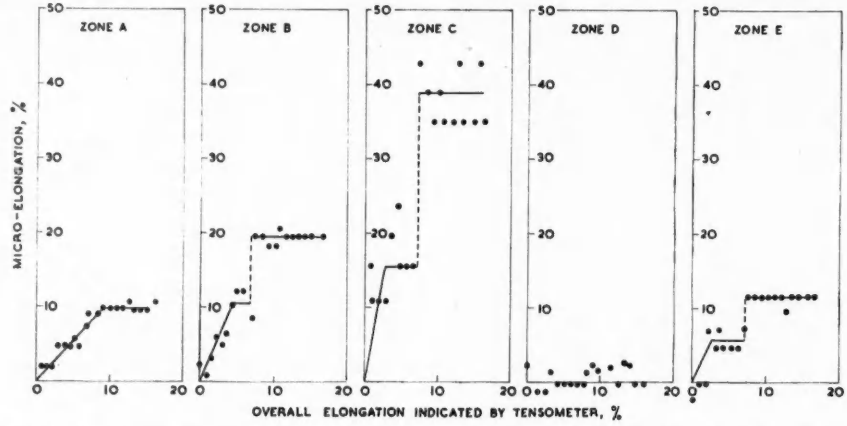
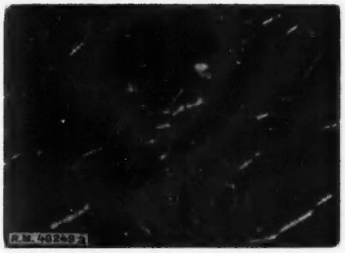



Fig. 10. **Tensile test on mild steel of 0·004 in. grain size. Micro-elongation observed in five neighbouring zones of the micro-region outside the zone of necking.**



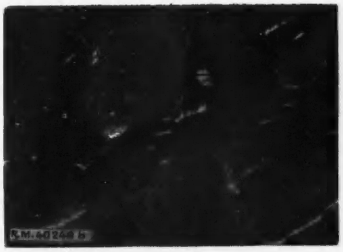


Fig. 11. **Sudden appearance of deformation bands in certain crystals of the observed region outside the zone of necking in a tensile test on mild steel of 0·004 in. grain size.**

(left) End of second stage of plastic micro-deformation.

(right) Start of third stage.

Fig. 12. **Gradual appearance of deformation bands inside the zone of necking in a tensile test on mild steel of 0·004 in. grain size.**

(left) 2·5 per cent overall elongation.

(right) 13·5 per cent overall elongation.

arrest at one constant level (Fig. 9). It therefore appears that, of the three stages observed before, the first two have combined, or, rather, that several sudden but slight discontinuities appear at different moments during the test. The irregularities are thus blurred if a large number of grains is involved in the measured micro-elongation ; they might therefore be accentuated if the scale of the micro-measurements is further reduced so as to cover one grain only. A reduced scale unit applied to the photographs of the sample Fig. 7 (centre), permitted measurement and plotting of the micro-elongation in five small neighbouring zones of the micro-region observed, each zone covering one grain only (Fig. 10). It is seen that one grain shows no plastic deformation at all (Zone D), another shows hardly any irregularities (Zone A), while the remaining three have all the features of Fig. 7. Outside the zone of necking, we thus have a great irregularity of surface deformation of the tensile specimen, with one outstanding phenomenon : the two different, constant, levels of plastic micro-deformation, separated by an abrupt discontinuity.

The micro-elongation *inside the zone of necking*, if plotted as a function of the overall elongation (Fig. 8), shows two stages of plastic deformation :—(1) the proportional stage and 45 deg. line as before, and, (2) a much more rapid increase of micro-elongation than would correspond to the respective further increase in overall elongation. The second stage sets in at the relatively small strain of about 12 per cent when necking cannot yet be observed macroscopically. The deformation bands do not appear suddenly, but are formed gradually within the crystals. They no longer extend right to the grain boundaries (Fig. 12).

### B. Interpretation of Results.

If we imagine that each grain consists of a ferritic ductile interior surrounded by a practically undeformable " crust " containing cementite, then the observed discontinuities of the micro-elongation of the single grains might well be attributed to ruptures in that crust. The fact that, inside the zone of necking, the deformation bands stop short of the grain boundaries also suggests the existence of a hard crust, and the different behaviour of different grains seems to point to separate modes of deformation of crust and interior. Suppose that the ductile interior deforms, and that the crust resists deformation and begins to slide on the interior. If the friction forces of this sliding movement are small compared with the forces which would be needed for a deformation of the crust, then the entire crystal will be distorted in such a manner that the crust itself deforms as little as possible. Under these conditions, for instance, a spherical body, as can be shown mathematically, may deform into an ellipsoid with, say, 11·8 per cent elongation of the major axis, while the maximum linear strain inside the crust still remains below 1 per cent.

Thus, the first stage of plastic micro-deformation *outside* the zone of necking (proportional increase) would correspond to the ordinary plastic behaviour of the ferritic grain interior under the simultaneous action of five slip systems. This stage would lead up to a linear grain extension of 7 to 12 per cent (see Figs. 7 and 10) with hardly any deformation of the cementite-base crust and without the appearance of deformation bands at the metal surface. The crust, by binding and holding the interior, would ensure the regularity of this deformation. The first stage ends when the stresses in the observed micro-region have become so large that any further increase would lead to local rupture in the crust. Plastic deformation then stops completely in the observed region because further parallel slip has become impossible (second stage). As tension increases with the continuation of the test, the crust finally breaks at different points, thus freeing the way for further slip, and a sudden large plastic micro-deformation takes place with the appearance of deformation bands at the surface of the micro-region, since the crust is no longer coherent. After that, plastic deformation is completely and finally arrested in the observed region. The different behaviour of the metal *within* the zone of necking could be explained by local weaknesses in the cementite-base crust. Because of these weaknesses, the crust cannot here interrupt the continuance of slip, and considerable plastic micro-deformation is encountered at a fairly early stage of the test, accompanied by a gradual appearance of deformation bands.

## PROVISIONAL CONCLUSIONS

(1). Even in simple tension, widely different mechanisms of rupture can be observed : Pure cleavage, cleavage with tearing of crystals, parallel slip followed by tearing. The first two always and exclusively determine the fracture of zinc when tested cold. The third one occurs in mild steel with its many possibilities of slip, and in zinc tested at elevated temperatures where the critical shear stress decreases rapidly.

(2). Premature cracks are often observed in zinc but do not lead to final fracture because the plasticity of neighbouring crystals probably prevents their propagation. The total possible plastic deformation of zinc, however, remains very small and irregular, affecting only a certain number of grains.

(3). Twinning plays only a secondary role in the mechanism of rupture.

(4). In zinc as well as mild steel, the mechanisms of deformation and rupture are heterogeneous. In zinc, the modes of fracture differ from one grain to the other; in steel, slip is momentarily inhibited in various grains by a binding action of the cementite-base crust surrounding the ferritic grains.

(5). Neither in zinc nor in mild steel did intercrystalline separation occur before final fracture. Even at the last moment of fracture, it only occurred in exceptional cases. No observed fracture was entirely intercrystalline, and intercrystalline cracks seemed to develop only at points where the orientation of a crystal precluded any cleavage inside the grain.

(6). Simple tension of mild steel at room temperature leads to slip followed by tearing within the grains after appreciable cold work. The phenomena are complicated by the presence of a cementite-base crust which is but slightly deformable.

SWITZERLAND

# Quick-Acting Voltage Regulators Designed According to Generator Size

By A. ERNST and P. BIVERONI. (From *Bulletin Oerlikon*, No. 282, January-February-March, 1950, pp. 1992-2008, 36 illustrations.)

*This article describes the Oerlikon a.c. and d.c. automatic voltage regulators designed for generators with outputs ranging from 50 kVA to 30 MVA. The effects of the generator and exciter on the control process are outlined and detailed descriptions are given of the direct-acting rolling sector regulators and the high-output regulators with hydraulic control.*

THE basic principle of the Oerlikon automatic voltage control system for generators, giving quick-acting regulation, is shown in Fig. 1. When voltage fluctuations occur, the measuring element $M$ of the regulator exerts a pull on spring $F$ and operates the control element $R$. The rolling sector of the controller is then rotated away from its neutral position and thus varies the resistance in the shunt circuit of the exciter $E$. To avoid hunting effects, the arrangement is stabilised by a damper $D$ and a restoring spring $Rf$.

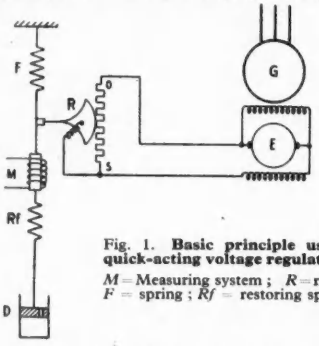



Fig. 1. **Basic principle used for automatic quick-acting voltage regulation of a generator.**
$M$ = Measuring system; $R$ = regulating resistance; $F$ = spring; $Rf$ = restoring spring; $D$ = damper.

The spring $Rf$ between $M$ and $D$ allows a short period of over-regulation to overcome the inertia of the exciter and generator. The object is to obtain a control process with the smallest possible time constant. Particularly favourable results are achieved if the spring stiffness of $Rf$ and the damping coefficient of $D$ are so chosen that the process will occur as an oscillation of decreasing amplitude which is damped out in about 2 cycles.

*The effect of the generator on the control process* is as follows:—If the exciter voltage is varied by a value $\Delta U$ while the generator is running under no-load conditions, the exciter voltage and the generator voltage will adjust themselves to a new stationary value $U_2$ following an exponential curve with a time constant $T$.

At any instant, the voltage deviation $f$ of the generator is then proportional to the area bounded by the curve representing the exciter current variation and the horizontal line $U_{e2}$ of the exciter voltage. This indicates that the control process can be effectively accelerated by means of over-regulation, that is, by dropping the exciter voltage to a value below the final value, and that negative, i.e., reverse excitation may be employed if necessary.

The time constant of a circuit is determined by the ratio $T = L/R$ of the inductance and the ohmic resistance of the circuit. By adding the time constant $T_E$ of the exciter to the generator constant $T_G$, the approximate value of the time constant $T$ for the entire group of machines is obtained. Although $T_G$ can be reduced by increasing the resistance in the rotor circuit or by increasing the air gap, these changes would require a greater power output from the exciter and are, therefore, very seldom used. A much simpler means of reducing the time constant of the control process is by providing for over-regulation.

The no-load time constant $T_G$ of synchronous generators varies according to the type of machine and the power output. Typical ranges of values are given in the following table:—

| Power [MVA] | 2·0 | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|---|
| $T_G$ for salient-pole generators [sec] | 1·7-3·0 | 2·5-6·5 | 3·2-8·0 | .. | .. | .. |
| $T_G$ for turbo-generators [sec] | .. | .. | .. | 4·9-7·5 | 5·3-7·8 | 5·5-7·9 |

The time constant of a network with several machines is a mean value taking account of the relative sizes of the machines, and it is mainly determined by the time constant of the largest generator. The network constant is affected to a much lesser extent by asynchronous motors, and is not at all affected by transformers, resistances and capacitances.

In order to maintain constant generator voltage, the exciter current will increase following a hyperbolic law when the active current of the synchronous machine operating at constant voltage and frequency is varied.

The greatest deviations in generator voltage from the required value occur after sudden load changes.

With a reactive load drop, the generator voltage drops owing to the decrease in stray voltage due to the increase in current in the stator windings. The temporary variation in rotor current is not caused by the exciter but is produced by the reaction of the stator current variation. The exciter voltage remains practically constant during the process. With an ohmic load change, occurring either in the generator or the motor circuit, the variation is similar to that produced by a reactive load change, except that the stray voltage drop is much larger.

*The effect of the exciter on the control process* may be summarized as follows :—If a variation $\Delta U$ occurs in the voltage of the field winding of an exciter-type machine, the field current and the voltage of the exciter adjust themselves also to a new stationary value, as previously described in the case of a generator. The exciter time constant $T_{Exc}$ varies also as a function of the generator power. Typical ranges of values for $T_{Exc}$ under no-load conditions for machines with external excitation are given in the following table :—

| Power [MVA] | 20 | 40 | 60 | 80 |
|---|---|---|---|---|
| $T_{EXC}$ [sec] | 0·5-1·0 | 0·95-1·5 | 0·65-1·45 | 0·75-.. |

*Machines with shunt field excitation* require simpler installations. The conventional shunt-wound generators are not suitable as exciters, since their regulating range is too small. Nowadays, practically all shunt field exciters have regulator poles which allow stable regulation down to very low values.

The exciter voltage increases when the voltage

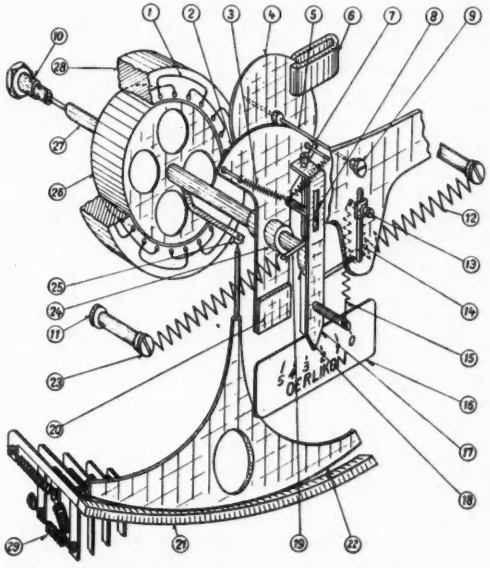



**Fig. 2. Basic design of the rolling sector regulator.**

1 = Windings of the rotating system ; 2 = sector providing restoring action ; 3 = restoring spring ; 4 = damper disc ; 5 = damper spindle ; 6 = damper magnet ; 7 = adjusting screw for restoring spring ; 8 = scale for adjustment of restoring action ; 9 and 10 = pivot points ; 11 = eccentric screw for main spring ; 12 = main spring ; 13 = adjusting screw for static spring ; 14 = scale for adjustment of static factor ; 15 = static spring ; 16 = scale for position of rotating system ; 17 = pointer ; 18 = main spring pulley ; 19 = tensioning strip ; 20 = balance weight for restoring sector ; 21 = contact path ; 22 = contact sector ; 23 = adjusting screw for main spring ; 24 = bearing bush for restoring sector ; 25 = jewel bearing for contact sector ; 26 = rotor ; 27 = rotor spindle ; 28 = stator ; 29 = regulating resistances.

regulator alters the field circuit resistance. The rate of increase of the excitation voltage is limited because the regulator resistance cannot be adjusted to a value lower than that corresponding to the resistance of the field winding.

*Machines with external excitation* react much more rapidly, and modern standard high-power generators are generally of this type. The external voltage is nearly always provided by a direct-coupled self-excited auxiliary exciter adjusted to a constant voltage.

The *voltage regulator* must be of ample size to give rapid control over a wide operating range, with a regulating resistance enabling over-regulation to be obtained under extreme conditions, that is, for zero load at minimum voltage and for full load at minimum $\cos\varphi$ (inductive load).

The time constant of a good quick-acting regulator is of the order of a few hundredths of a second, and is therefore about 100 times smaller than the time constant of the generator and the exciter. The voltage regulator performance can also be assessed by the time required for it to run at maximum torque from one end of its range to the other when the damping and restoring forces are inoperative. This is frequently referred to as the " falling-off time " of the regulator.

## DESIGN PRINCIPLES AND OPERATION OF THE OERLIKON QUICK-ACTING VOLTAGE REGULATORS

1. Rolling Sector Regulators. These are direct-acting regulators, that is, their measuring system acts directly on the regulating resistance which takes over the functions of the field rheostat.

The details of a regulator are shown in Fig. 2. The regulator consists of (a) an electrical measuring system with elastic restoring force and damping, and (b) a regulating system. The entire unit is built into the switchboard. The mechanism with the contact path on the front side of the light-metal base plate is protected by an easily removable dust-proof cover. The measuring system and the resistor elements are situated behind the base plate and are enclosed in a perforated sheet-metal casing.

*For a.c. regulators*, the measuring system is single-phase and consists of a slotted stator, provided with two windings with currents 90 degrees out of phase, and a rotor supported on points elastically mounted in jewel bearings. The rotor drum is built from metals with high electrical and magnetic conductivity, and the measuring unit, in spite of its small VA consumption, is thus capable of producing considerable torque. For *d.c. regulators* a dynamic measuring system is used, in which the field coil and the rotating coil are connected in series.

The electrical torque is resisted by two main springs which act on the rotor shaft via a tension pulley. As a result of the spring characteristics, the electrical torque produced is greater at one end position of the rotor than at the other. The first end position corresponds to the zero load condition for the generator, and the regulated voltage is, therefore, somewhat higher than in the second case, which corresponds to the full-load operating condition for the generator. The slope of the characteristic representing voltage plotted against regulator displacement is known as the " static factor " of the regulator and is expressed as a percentage of the no-load voltage.

The value of this static factor can be varied by means of an astatic spring, arranged so that its torque will act with that of the main springs over one half of the regulating path and oppose it over the other half. By adjusting the tension of the astatic spring, the static factor can be reduced, cancelled out or even over-compensated (hyperstatic case). It the static factor of the main springs is cancelled out, so that the resultant

torque of the main springs and the astatic spring is constant over the entire regulating range, the regulation is said to be " astatic " and the voltage is then regulated to a constant value irrespective of the generator load.

The measuring unit is provided with an elastic restoring member and a damper. The restoring sector is mounted so that it can rotate freely on the shaft of the measuring system, but it is elastically connected to this shaft by means of restoring springs. The tension of these springs can be increased by shifting their point of attachment further away from the sector, this being achieved by means of an adjusting screw in a vertical slot in the pointer. The restoring sector is coupled through a gear arrangement to an eddy-current brake consisting of an aluminium disc rotating between the poles of a powerful magnet. The braking effect increases with increasing velocity of rotation.

The rotor of the measuring unit acts on the rolling sector. This sector is operated by a point which is elastically mounted in a jewel bearing. It is also supported by a guiding groove in the contact path and successively touches all the contact segments. The upper surface of these segments and the rolling surface of the sector are of solid silver. Particular attention has been given to the production of these parts, which are most important for regulator sensitivity. A resistor coil is connected to each segment of the contact path so that when the sector rolls over these segments, a number of these coils are short-circuited.

*Operation of regulator.*—In the case of a slow voltage variation caused, for instance, by a gradually increased load, the electrical torque will no longer be equal to the spring torque. The rotor then begins to rotate and the restoring sector and damper disc are capable of following it at speeds corresponding to slowly increasing loads. The rotating sector is also rolled down over a portion of the contact path and varies the value of the regulating resistance, which affects the excitation, until the required value of the terminal voltage is obtained again and the rotor comes to rest at a different position.

In the case of a larger voltage variation, the behaviour of the regulator is different. After a negligibly small time lag, the rotor and, therefore, the rolling sector start operating, but their motion is too rapid to be followed by the restoring sector which is slowed down by the damper. In this case, the rolling sector will move to a position beyond that corresponding to the new load condition, but in so doing it will increase the tension of the restoring springs, which will thus give rise to a returning motion with increasing generator voltage, while the restoring sector is following the initial motion of the rotor as rapidly as is allowed by the damper. The rotor is thus brought back to the new stationary condition at the right instant, and the restoring sector and the damper disc also reach this position simultaneously.

By means of this instantaneous over-regulation, the magnetic inertia of the exciter is compensated, so that the voltage variation of the generator will take place rapidly. Both the tension of the restoring springs and the damping factor are adjustable and the control process is, therefore, easily adaptable to the characteristic of the machine which is to be regulated.

2. HIGH-OUTPUT REGULATORS WITH HYDRAULIC CONTROL.—These are employed for the regulation of very large generators, for which the regulating range and torque output of the rolling sector regulators are not sufficient. The high-output regulators incorporate the same measuring unit and the same restoring and damping systems as the smaller regulators.

The regulating system consists of two commutators with laminations connected to the tappings of the regulating resistance. Instead of the rolling sector, carbon brushes fixed to a rotating arm are used. This rotating arm is actuated hydraulically by means of a servo-motor controlled by the measuring unit. Each position of the measuring unit corresponds to only one position of the servo-motor, and the adjustment of the regulating resistance is thus fully determined.

The hydraulic control system comprises two basic parts : (a) a control system, which acts as an amplifier, and (b) a hydraulically operated servo-motor, which is the actual regulating element.

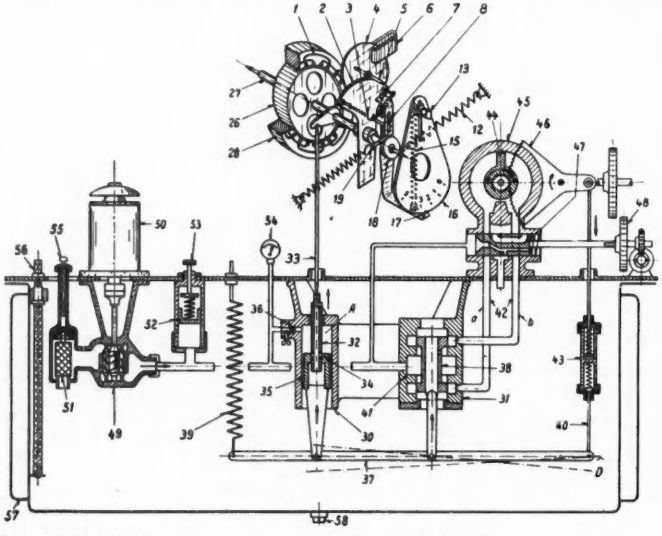


Fig. 3. **Schematic drawing of the high-output quick-acting regulator with hydraulic control. Measuring system and control unit.**

1 = Windings of the rotating system ;
2 = restoring sector ;
3 = restoring spring ;
4 = damper disc ;
5 = damper spindle ;
6 = damper magnet ;
7 = adjusting screw for restoring spring;
8 = scale for adjustment of restoring action ;
12 = main spring ;
13 = adjusting screw for static spring ;
15 = static spring ;
16 = scale for position of rotating system ;
17 = pointer ;
18 = main spring tightening drum ;
19 = tensioning strip ;
26 = rotor ;
27 = rotor spindle ;
28 = stator ;
30 = pilot control cylinder ;
31 = main control cylinder ;
32 = pilot control sleeve
33 = coupling rod ;
34 = control slots ;
35 = pilot control piston
36 = orifice ;
37 = double lever ;
38 = main control piston ;
39 = spring for pilot control piston
40 = rod for restoring action ;
41 = pressure-oil inlet ;
42 = pressure ducts to servo-motor;
43 = spring bush ;
44 = rotating vane of servo-motor ;
45 = hydraulic servo-motor ;
46 = gear sector for rigid restoring action ;
47 = reversing valve ;
48 = reverse gear ;
49 = oil pressure pump;
50 = pump motor ;
51 = oil filter ;
52 = relief valve ;
53 = adjusting screw of relief valve ;
54 = manometer ;
55 = oil dip stick ;
56 = shaft for lowering the oil tank ;
57 = oil tank ;
58 = oil drain plug.

The control system is shown in Fig. 3. It consists mainly of a pilot control valve (30) and a main control valve (31), both of which are enclosed in a common casing and operate completely immersed in an oil bath. This also applies to the screw pump (49) supplying the pressure oil and to its oil intake and filter (51), so that any possibility of air locks in the hydraulic system is obviated.

The motion of the measuring system is transmitted by means of a linkage, free from play, to the pilot control sleeve (32) which goes into the pilot control piston (35). As long as the latter covers the control slots (34) of the pilot control sleeve (32), it will move downwards under the pressure of the oil entering the cylinder space (A) through the orifice (36), until it finally uncovers the control slots. The pilot control piston then reaches an equilibrium position as soon as the amount of oil continuously flowing through the control slots (34) is sufficient to reduce the oil pressure in space (A) to a value at which the pressure acting on the pilot control piston will be equal to the pull of the spring (39).

If the pilot control sleeve moves still further downward, it will be followed by the piston until it again reaches a new equilibrium position. Similarly it will follow any upward motion of the sleeve as a result of the pull exerted by spring (39), which is no longer compensated by the reduced oil pressure in the space (A) when the control slots are opened beyond a certain position. The pilot control piston, therefore, immediately, follows any motion of the control sleeve (34) and, hence, of the measuring system to which it is connected. Each position of the measuring system corresponds, therefore, to one well-determined position of the pilot control piston.

During the motion of this piston, the lever (37) rotates about the instantaneous position of the fulcrum (D) and transmits a corresponding vertical motion to the control piston (38) of the main control valve. The two oil outlet orifices of the main valve, which were closed when the measuring system was in its neutral position, are now opened, and this occurs in such a way that, for instance, after an upward motion of the piston (38), pressure oil from the central annular channel of the main valve enters the duct (42b), whereas duct (42a) is connected with the oil reservoir.

The hydraulic servo-motor (45) consists of a fixed annular chamber with a protruding lug, and a rotor with a vane dividing the chamber into two spaces with different pressures, which are connected to the main control valve through the oil ducts (42a) and (42b). When this main valve is operating as previously described, pressure oil is fed into the chamber on the right, while oil flows out of the left-hand chamber. The rotating vane will, therefore, be displaced in a counter-clockwise direction. At the same time, the linkage (40) providing the restoring action will be moved downwards by the gear sector (46) so that, although the pilot control piston remains stationary, the main control piston will be brought back again to its neutral position. The restoring system is rigid only to a certain extent, owing to the effect of the compression springs in bush (43), and becomes elastic when the regulating force exceeds a certain value.

By means of the restoring system, a well-determined relationship is obtained between the position of the rotating vane of the servo-motor and that of the pilot control piston (35) and, hence, of the measuring system. Thus, the corresponding positions of the measuring system and the regulating system are fully determined throughout the regulating process.

CZECHOSLOVAKIA

# The Measurement of Surge Voltages

By B. Novák. (From *Elektrotechnicky Obzor*, Vol. 39, No. 13, 1950, pp. 281-286, 10 illustrations.)

*The author criticises the usual methods for surge voltage measurements and proposes an indirect method which, by means of fluxmeters, indicates the electrical charge of the wave.*

Electrical surge waves are characterised by the peak voltage and the wave form. The shape of the wave is determined by the capacitance and resistance values of the surge circuit, which are usually not varied during testing. The peak voltage, on the other hand, is regulated by the setting of sphere gaps.

The testing of lightning arrestors for low voltages of about 1 kV with electrical surges requires accurate measurement of the peak voltage. The available methods of measurement are those using the following : (a) sphere gaps, (b) neon glow-discharge lamp, and (c) oscillographs.
These, however, are not satisfactory for the purpose indicated. Sphere gaps are generally very slow for testing, because a large number of measurements is required to obtain the necessary accuracy. When very low voltages are measured, the spheres have to be replaced by points, which, due to arcing, rapidly become inaccurate. The voltage indication of neon glow-discharge lamps with a variable condenser is reliable. The glow, however, is not easily detected by the person testing, because the eyes are rendered insensitive by the surge sparks.

The cathode-ray oscillograph can be used for the visual or photographic method of voltage measurement. The method is not sufficiently accurate and errors may be of the order of 10 per cent. When the surge waves have oscillations superposed on them, these three methods of peak voltage measurement are disadvantageous, because they indicate a voltage corresponding to the peak of the uppermost oscillation. Such oscillations are present in most surges, and these indications are somewhat higher than those for a wave without oscillations, but of the same charge.

A new indirect method for the voltage measurement of surge waves uses fluxmeters, which indicate the electrical charge of the wave. The method follows from a detailed analysis of the voltages $e$ and the currents $i$ in the tested object (given in the original article). Fig. 1 shows two usual circuits for testing with surge generators, where $C_1$ is the capacitance of the generator, $C_2$ that of the tested object, and an additional capacitance $R_1$ is the front and $R_2$ the tail resistance. The curves for

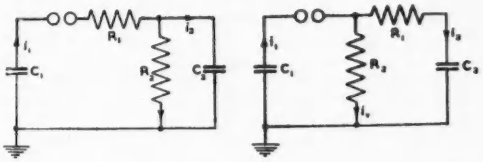



Fig. 1

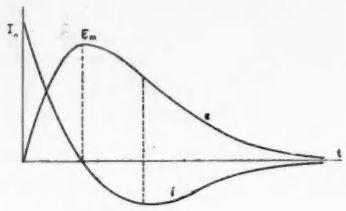



Fig. 2

voltage and current plotted against time $t$, for a surge discharge are shown in Fig. 2.

It is shown that the maximum voltage of the surge wave $E_m$ is directly proportional to the voltage of the generator $E_0$ at the onset of the discharge. Similarly, the current which flows from the surge generator or in the tail resistance $R_s$ is proportional to $E_0$, it being immaterial which of the test circuits in Fig. 1 is used. Therefore, the total charge $Q$ which flows during a surge through the tail resistance is also proportional to $E_0$. Integration of the expressions for the current show that $Q = E_0\ C_1$. As, however, $E_m = \eta\ E_0$, where $\eta$ is a constant, $E_m = \eta\ Q/C_1 = k\ Q$, or the peak voltage $E_m$ is directly proportional to the charge $Q$ of the wave, $k$ being a constant.

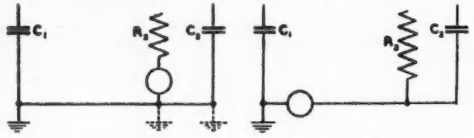



Fig. 3

The quantity of electricity $Q$ can be readily measured with a ballistic galvanometer or a fluxmeter by the two methods shown in Fig. 3. If the instrument is connected in series with the tail resistance (Fig. 3a), the instrument can be earthed separately. The readings are, however, correct in this case only when there is no spark-over

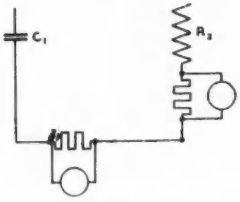



Fig. 4

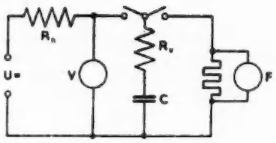



Fig. 5

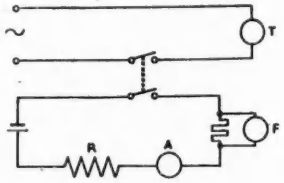



Fig. 6

across the tested object. If, however, the instrument is used in the way shown in Fig. 3b, such inaccuracies do not occur. In this case, only the surge generator can be earthed. This can be inconvenient when bulky objects are tested.

It appears that fluxmeters are preferable to ballistic galvanometers for these measurements. The arrangement of a ballistic suspension galvanometer with light source, telescope, etc., is rather inconvenient to handle, except where the whole system is built into one box. Galvanometers the moving coils of which are mounted in bearings are simpler to handle. Generally, when the galvanometer is connected as shown in Fig. 4, the shunt resistance of the instrument, which changes the sensitivity, has to be small, so as not to vary considerably the total resistance of the circuit and thus not to cause a large voltage drop. On the other hand, with a small resistance, the return movement of the needle and the taking of readings becomes slow. A further disadvantage is the tiring effect of the large number of readings on the observer.

The fluxmeter has no such disadvantages. The important requirement that the shunt resistance should be as small as possible is favourable for the damping of the fluxmeter. Such a resistance is of the order of a few ohms. The taking of readings is easy, because the needle stops in the maximum position. When the tested object is repeatedly subjected to surges of the same magnitude, it is sufficient to read off the sum of the single deflections of the pointer of the fluxmeter and divide by the number of surges. A good average value of the surge voltage is obtained in this way.

The accurate instrument for this purpose is the suspension type of fluxmeter. This instrument, however, requires the use of an auxiliary current to return the needle to the zero position after every measurement. Further, this instrument is not sufficiently robust and, therefore, a fluxmeter on bearings is preferable. The sensitivity of such an instrument is not smaller than that of the suspension type; the friction in the bearings, however, introduces errors.

In arranging measurements on the surge generator with the fluxmeter, the usual precautions have to be taken, i.e., full screening of the shunt resistance, which is near the generator; screening of the connecting wires from the shunt to the fluxmeter, etc.

The frictional forces in the bearings of the fluxmeter are static and dynamic. The errors caused by the static frictional forces which arise at the very beginning of the movement of the needle can be large. Fig. 5 shows the arrangement for the measurement of these errors in a fluxmeter. Accordingly, the capacitor $C$ is charged from the source $U$ to a certain voltage $V$. The charge $Q$ of the capacitor is subsequently discharged through the fluxmeter, resulting in a deflection corresponding to a charge $Q^x$. This deflection is smaller than that due to the same charge flowing through the fluxmeter under constant current conditions. The difference between $Q$ and $Q^x$ is the error caused by static friction. The magnitude of this error is approximately inversely proportional to the measured charge, e.g., it averaged 2 per cent in an instrument for the range of 0·05 to 10 mA.

The influence of the dynamic friction on the accuracy of the measurements can be determined by the arrangement shown in Fig. 6. Constant currents of varying magnitude pass through the instrument $F$ for a time interval measured by the instrument $T$ and the corresponding deflections are plotted. The dynamic friction produces a constant opposing couple to the rotation of the coil, and there is a minimum current $I_0$, below which the needle comes to rest. It is usually found that the minimum current is very small compared with the current of the surge wave and, therefore, the error introduced by dynamic friction can be neglected. (A correction due to this type of error is necessary when the surge waves are of very long duration).

In conclusion, fluxmeters of the bearing type can be used in preference to other methods for the indirect measurement of the peak voltage of surge discharges, especially when the voltage is low.

# A Survey of Low-Temperature Properties of Metals

By E. J. RIPLING. (From *The Iron Age*, Vol. 166, Nos. 16 and 17, October 19 and 26, 1950, pp. 76-80 and pp. 53-57 respectively, 12 illustrations.)

*Steels for use at low temperatures should be fine-grained and thoroughly de-oxidised. Distribution of carbides should be spheroidal rather than lamellar. Tempered martensitic steels behave more favourably at low temperatures than pearlitic steels. Face-centred cubic metals (most aluminium and copper-base alloys, and austenitic steels) retain their toughness and ductility even at very low temperatures. The poor low-temperature performance of martensitic steels tempered near 600° F, and of most annealed steels, is at least partly rheotropic.*

THE hardness, yield strength, ultimate strength, fatigue strength and elastic modulus of metals and alloys increase with decreasing temperature. The ductility and toughness may increase, remain constant, or decrease, depending on the metal and the temperature range.

The outstanding example of a metal becoming brittle at low temperatures is steel, the change in ductility and toughness generally occurring within a narrow temperature range, as shown in Fig. 1. The increase in the severity of any of the embrittling agents moves the "transition temperature" to higher values. A considerable amount of data is available on the effect on transition temperature of embrittling agents, strain rate, and state of stress. The effect of test section size has not, however, so far been systematically investigated.

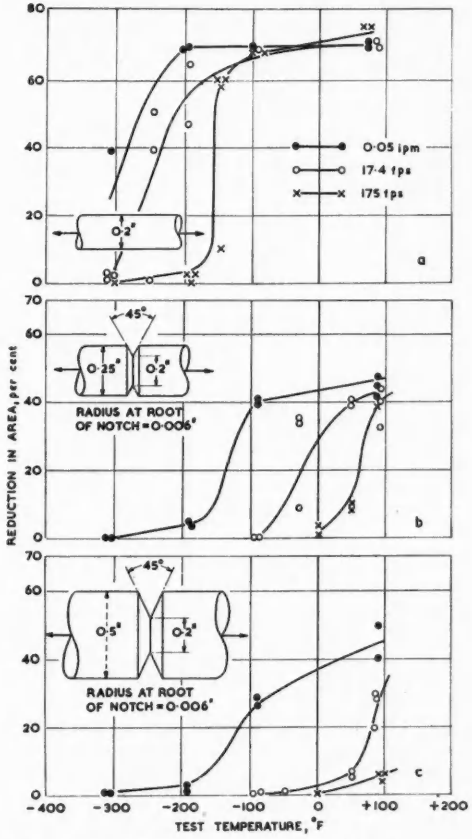



Fig. 1. **Effect of testing temperature on ductility under various testing conditions, showing that major ductility changes are limited to a narrow range.**

The stress state, i.e., whether the stress is uni-, bi- or triaxial, is varied by using specimens of different shape, e.g., the straining of a notched bar produces a triaxial stress state, the effect of which can be varied over a wide range by varying the radius at the bottom of the notch, the angle and depth of the notch.

Results of investigations on a 0·17 per cent carbon steel are shown in Fig. 1, the effect of the variation of strain rate being given, Fig. 1a, while the influence of the notch depth on the transition temperature can be seen in Figs. 1b and 1c. Similar investigations have been made on other steels and an aluminium alloy.[1]

Transition phenomena similar to Fig. 1 are observed if the test temperature is kept constant, and the strain rate or the notch severity is used as an independent variable. If a steel under some particular application is near its transition value, measured in terms of any of the embrittling agents, a slight variation of any of the other agents may bring about the transition to the brittle state. However, no quantitative relation in general can be established between temperature, strain rate and notch severity.

To obtain a transition temperature in a region that is readily obtainable in the laboratory, a mild notch and a moderately fast strain rate are satisfactory for most structural steels. For this reason, the Charpy impact test has been widely used for evaluating transition temperatures. Other specimen shapes and loading rates can be used, but transition temperatures will only be comparable if obtained under the same straining conditions.

The definition of transition temperature is still the subject of discussion, and it is sometimes given as the range over which ductility suffers a rapid change, while at other times particular points on the transition curve are selected, such as the end-points or the point of inflexion of the steep part of the curve (c.f. Fig. 1.)

When the ductility of the specimen changes from a high to a low value, the fracture also changes from a shear to a cleavage type. Consequently, transition temperature is sometimes given as that corresponding to some arbitrary percentage of cleavage fracture. Another suggestion recently made was to define transition temperature as the temperature where the toughness is 80 per cent of the maximum (ductile) value. It is observed that this is also the lowest temperature at which 100 per cent shear fracture is obtained with heat-treated steels.

Investigations have recently been made on the relation between low-temperature strength and notch severity of a 2·75 Si steel.[2] The results, some of which are shown in Fig. 2, indicate that the fracture stress-temperature curves are all sections of a complex curve containing a minimum and a maximum at some low temperature. The positions of these minima and maxima move to higher temperatures as the notch severity is increased.

These data show a temperature range in which the tensile strength increases with decreasing temperature, while in another range it decreases. This is due to the lowering of the ductility over the temperature range

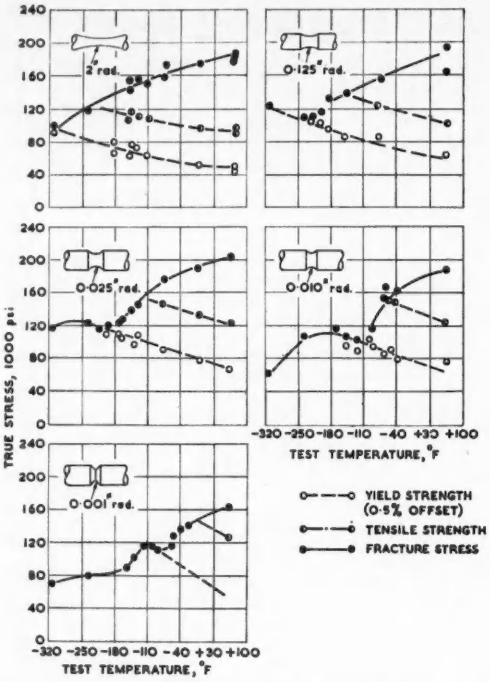



Fig. 2. **Curves showing the varied effect of notch radius on the low-temperature strength properties of a 2·75 per cent Si Steel.**

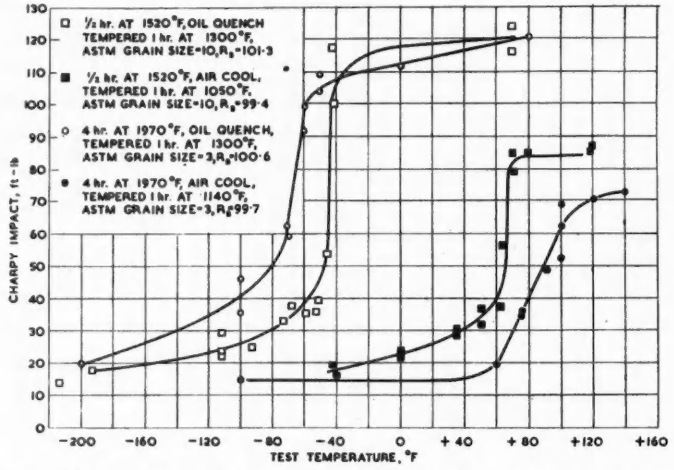

½ hr. AT 1520°F, OIL QUENCH TEMPERED 1 hr. AT 1300°F, ASTM GRAIN SIZE=10, $R_A$=101·3
½ hr. AT 1520°F, AIR COOL, TEMPERED 1 hr. AT 1050°F, ASTM GRAIN SIZE=10, $R_A$=99·4
4 hr. AT 1970°F, OIL QUENCH, TEMPERED 1 hr. AT 1300°F, ASTM GRAIN SIZE=3, $R_A$=100·6
4 hr. AT 1970°F, AIR COOL, TEMPERED 1 hr. AT 1140°F, ASTM GRAIN SIZE=3, $R_A$=99·7
CHARPY IMPACT, ft-lb
TEST TEMPERATURE, °F

Fig. 3. **Effect of micro-structure and grain size on the transition temperature of SAE 3140 steel. The martensitic material has a lower transition temperature and greater toughness at temperatures above the transition temperature.**

considered to such an extent that the tensile strength becomes dependent on the ductility, indicating that the metallurgical variables which contribute to good low-temperature behaviour are the same which contribute to better performance under severe stresses at normal temperatures. Hence, steels to be used at low temperatures should preferably be fine-grained and thoroughly de-oxidised. The distribution of the carbides should be spheroidal rather than lamellar.

Other investigators[3] considered martensitic and pearlitic steels of the same hardness (about $100R_B$). They found that the martensitic steels had lower transition temperatures and greater toughness above transition temperature than the pearlitic steels. Data for one of the steels tested, SAE 3140,* are shown in Fig. 3. Quenching from the temper was also found to improve low-temperature performance.

The effect of tempering temperature on the properties of quenched low-alloy structure steels at low and room temperatures has also been investigated.[4] Fig. 4 shows some of the results, various properties being expressed as functions of the tempering temperature. A noteworthy feature of the curves is the presence of maxima and minima respectively at a tempering temperature of about 600° F.

Results of experiments by the author[5] on the dependence of low-temperature ductility on tempering temperature may be summarised thus :—The ductility minima corresponding to a temperature of tempering around 600° F were found to persist at low temperatures up to −110° F. Investigations on the yield strength and tensile strength of the same steel (SAE 1340†) did not reveal minima of these quantities in the low-temperature range, for the 600° F tempering range. Since the tensile and yield strength are dependent primarily on the flow characteristics, these results indicate that the low-temperature flow properties of this steel are not damaged by the 600° F temper, as was the contraction in area (a fracturing characteristic).

The effect of steel composition on low-temperature properties has not so far been systematically investigated. However, the influence of carbon and nickel is important enough to be mentioned. Increasing carbon content reduces the toughness of steel, and more markedly so at low temperatures. The addition of nickel, on the other hand, decreases the transition temperature and also makes the transition more gradual.

If the composition of the steel is changed to such an extent that its structure is no longer body-centred cubic, it can no longer be considered in the same category with steels discussed here. For example, investigators of stainless steels[6] have found a sharp decrease in ductility as a function of temperature only when the material was kept martensitic or ferritic (Fig. 5). When the composition changed so that the steel became austenitic (face-centred cubic structure), it no longer exhibited a transition temperature. In fact, the impact properties of the austenitic steel improved with decreasing temperature.

In discussing low-temperature properties, nonferrous metals must be considered in two groups. Practically all common structural materials, other than steel, crystallise in the face-centred cubic system (most copper, nickel and aluminium-base alloys) and do not lose their ductility at low temperatures. The other nonferrous materials, however, exhibit transition temperatures similar to that shown by steel. In general, only face-centred cubic metals possess low-temperature ductility.

Data on the ductility of non-ferrous metals are separated in Fig. 6 to distinguish face-centred cubic metals (A) from the others (B). Ductility measurements

*0·35-0·45 C, 0·6-0·9 Mn, max. 0·04 P, max. 0·05 S, 1-1·5 Ni, 0·45-0·75 Cr.

†0·35-0·45 C, 1·6-1·9 Mn, max. 0·04 P, max. 0·05 S.

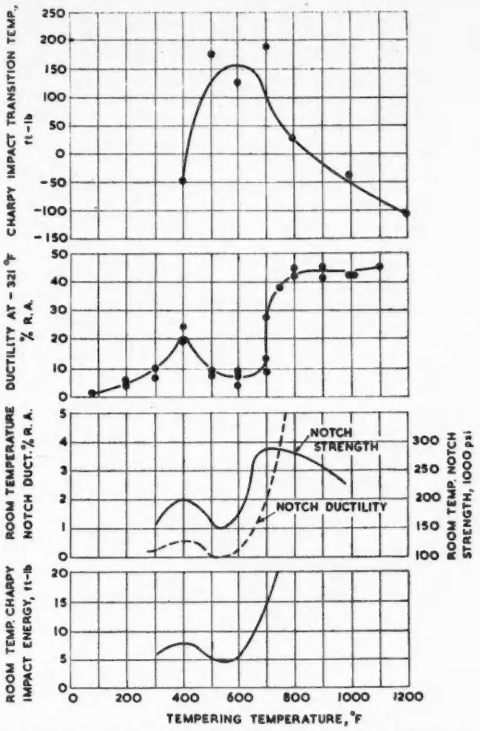

CHARPY IMPACT TRANSITION TEMP., ft-lb
DUCTILITY AT −321 °F % R.A.
ROOM TEMPERATURE NOTCH DUCT. % R.A.
NOTCH STRENGTH
NOTCH DUCTILITY
ROOM TEMP. NOTCH STRENGTH, 1000 psi
ROOM TEMP. CHARPY IMPACT ENERGY, ft-lb
TEMPERING TEMPERATURE, °F

Fig. 4. **Properties of quenched SAE 1340 steel as a function of the tempering temperature.**

other than contraction in area indicate that tungsten and molybdenum also show a transition temperature.

Research conducted to explain the fast decrease in properties in the vicinity of the transition temperature is hampered by the fact that only one fracturing point can be obtained for any particular testing condition. In consequence, it is difficult to evaluate the effect of any particular testing variable To overcome this limitation, a method of investigation was adopted which consists of straining a number of specimens by various amounts under one set of physical conditions (e.g., stretching an unnotched specimen at room temperature). These cold-worked specimens are then further deformed to fracture under a second set of conditions (e.g., by testing at a low temperature).

Results obtained by tests of this type are most readily analysed when the ductility retained after the second straining operation is plotted as a function of the deformation caused by the first operation (Fig. 7). The ductility value plotted here ("maximum natural strain") is the natural logarithm of the ratio of the original to the reduced area.

The aluminium alloy S24–T4* investigated has a face-centred structure and, consequently, does not show a transition temperature. Specimens were first strained by varying amounts at room temperature, then cooled to liquid nitrogen temperature (−321° F) and further stretched to failure. It should be noted that the effect of the pre-strain here was merely that of continuously lowering the ductility still available at the low temperature.

When other metals, showing a transition temperature between room temperature and −321° F, were subjected to the same straining[7], the retained ductility *vs.* pre-strain curve was of a more complicated type (Fig. 8). The pre-strain decreased the ductility available for the low-temperature test only over a limited range of strains. When the pre-strain exceeded these small values, the low-temperature ductility rose to a maximum before it began decreasing again to become equal to zero when the ductility was exhausted by pre-straining.

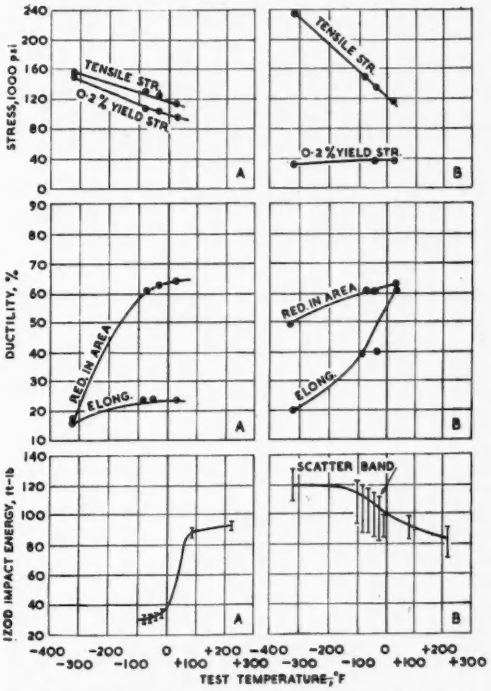



Fig. 5. **Low-temperature properties of two stainless steels: (A) martensitic type, 12 per cent Cr, 0·10 per cent C, hardened and tempered: (B) austenitic type, 0·28 per cent S, annealed.**

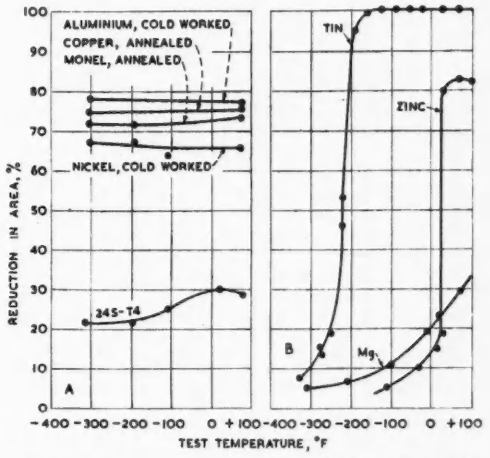



Fig. 6. **Low-temperature ductility of (A) face-centred cubic, (B) structures other than face-centred cubic, non-ferrous metals.**

*4·4 Cu, 0·5 Mn, 1·5 Mg. Solution heat-treated followed by rapid cooling and ageing at room temperature.

The part of the curve in Fig. 8 between A and B may be termed the stable branch.

Experiments on the effect of quenching and tempering at various temperatures between 300° F and 1100° F of the same metal (SAE 1340) subject to the same straining conditions gave the following result[7]: only steels showing a transition temperature between room temperature and – 321° F (those tempered at 400, 500, 600 and 700° F) gave complex retained ductility *vs.* pre-strain curves, while steels which did not show a transition temperature effect within this range exhibited simple curves similar to the aluminium alloy in Fig. 7.

This led to the conclusion that heat-treated steels which exhibit abnormally high transition curves are in some defective condition which can be overcome by prior working at room temperature. In order to determine the ductility in the absence of this defective condition, the end points of the extrapolated stable branches (zero pre-strain) were plotted as a function of the tempering temperature. These extrapolated values formed a smooth curve with the ductility points obtained at higher temperatures. The 600° F ductility minimum as well as the abnormally high transition temperatures

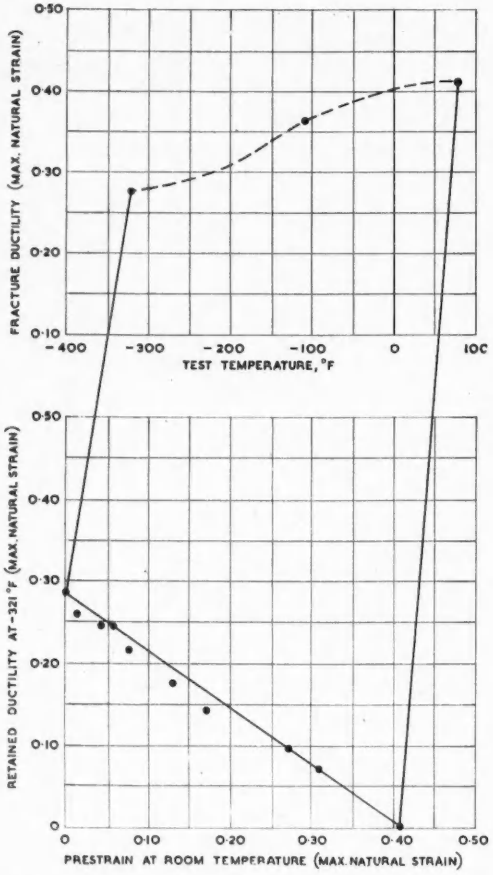



**Fig. 7. Effect of pre-straining at room temperature on residual ductility, 24S-T4 aluminium alloy. Residual ductility at zero pre-strain is equal to ductility at — 321° F; abscissa value for maximum possible pre-strain is represented by room temperature ductility, as shown by the tie lines.**

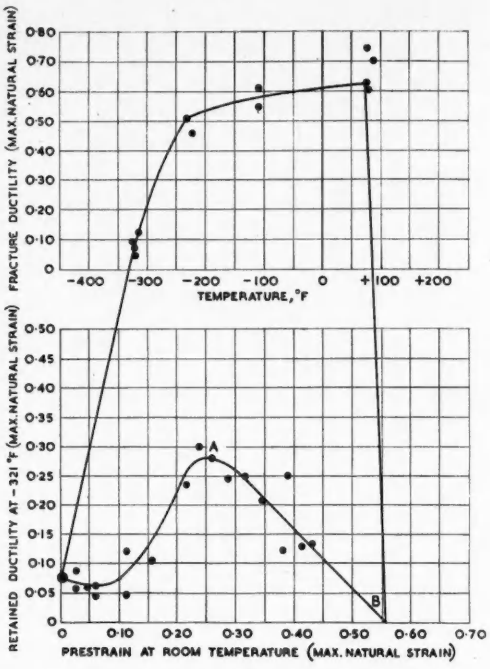



**Fig. 8. Curves showing effect of pre-straining at room temperature on residual ductility, SAE 1340, quenched and tempered at 600° F.**

were, as a consequence, thought to be the result of this strain-curable deficiency, which was termed "rheotropic embrittlement."

As stated earlier, the low-temperature behaviour of steels is closely associated with the severity of the stress condition. Experimental data show that in the presence of a sharp notch, the ductility, as determined by a static tensile test at room temperature, was very low for a number of steels tempered at about 600° F. It may be supposed that the sharp notch (60° "V" notch, radius at bottom less than 0·001 in.) used in these investigations was sufficiently severe to cause the transition temperature to exceed room temperature. Consequently, tests were carried out with unnotched specimens, quenched and tempered at 600° F. After a pre-straining at room-temperature, the sharp notch was machined into the specimens, after which they were stretched to failure at room temperature. As a result, the notch ductility of the steel was increased from less than 0·5 per cent at zero pre-strain to 2·5 per cent at a pre-strain of 30 per cent. This great improvement on room-temperature notch properties can only be expected if the material is such that the transition temperature lies below room temperature in the unnotched condition, and above room temperature in the notched condition.

REFERENCES.

(1) Proc. ASTM, Vol. 48, 1948, p. 643.
(2) Office of Naval Research, U.S. Navy Contract N6-onr-273/T. O. 1, Technical Report No. 16, March, 1949.
(3) Office of Naval Research, Contract N6-ori-71, T. O. IV, December, 1949.
(4) O.N.R., Contract N6-onr-274/T. O. 1, Technical Report No. 22, Sept., 1949.
(5) Trans. ASM, Vol. 42, 1950. "Tensile properties of a heat-treated low-alloy steel at subzero temperatures."
(6) Metal Progress, May, 1949, p. 643.
(7) "Rheotropic embrittlement of steel," Trans. ASM. (in print).

# Quantitative Measurement of Detonation Intensity in Internal Combustion Engines

By G. E. V. JONSSON. (From *Acta Polytechnica*, 1950, No. 62, Mechanical Engineering Series, Vol. 1, No. 10, 30 pages, 20 illustrations.)

*This is the second part of an article which describes a new method for the determination of the detonation intensity in internal combustion engines, based on rate-of-pressure-rise measurements made with a new type of pick-up insensitive to mechanical vibrations. Details of the pick-up and the associated electronic circuit, as well as of test results, are also given in this report which is the result of an investigation of the combustion process in internal combustion engines carried out at the Engine Laboratory of the Research Station of the Royal Swedish Academy of Engineering Sciences.*

(*Continued from January issue*)

## DETAILS OF THE ENGINE USED FOR TESTS

The engine employed for the tests was an Ethyl Gasoline Corporation test engine built in 1928. The engine originally had a fixed compression ratio, and for fuel tests the throttle position was varied. Since then it had been redesigned to enable the compression ratio to be varied. However, the first tests carried out by the author with the new detonation meter showed that considerable alterations to the engine were still required in order to be able to reproduce compression ratios, ignition timings and fuel-air ratios with sufficient accuracy. The engine was therefore reconstructed. The mechanism for raising and lowering the cylinder to vary the compression ratio was provided with strong guides with effective locking of the cylinder at the required position, and, in addition, the engine was fitted with new gearwheels, shafts and bearings for the camshaft and distributor drives.

The electromagnetically-controlled injection nozzle was fed from an accumulating fuel pump operated by the same cam as the intake valve. A contact was arranged on the camshaft for closing and breaking the circuit of the electro-magnet which lifted the spring-loaded valve of the nozzle. The injection lasted throughout 160 degrees of the crank rotation and was made at constant pressure by means of the accumulating fuel pump. The beginning of the injection could be adjusted to any desired position while the engine was running. As in these tests the engine was always run at full load, only the mixture strength had to be varied. This was achieved in a simple manner by adjusting the injection pressure so as to control the quantity of fuel. A low injection pressure of about 3·5 kg/cm² was used to obtain the correct fuel-air ratio, but the injection pressure could be varied from 2·5 to 5·0 kg/cm². Although this affected the atomisation to some extent, the effect was small compared with the effects of other factors on the atomisation and homogeneity of the fuel-air mixture.

Fuel consumption was measured by means of a flow-meter and by the constant-volume timing method. Air consumption was determined with a calibrated orifice plate. A large air chamber of 600 litres capacity was coupled between the engine and the orifice plate to eliminate pulsations in the air flow.

Constant intake pressure was maintained by means of an automatic device which kept the pressure in the air chamber at 740 mm Hg as long as the barometric pressure exceeded this figure. For complete elimination of the effect of barometric pressure, the back-pressure of the exhaust should also have been maintained at this value, but various circumstances prevented the use of an arrangement for this purpose.

The engine power was determined from the electric power delivered by a generator. The temperature of the fuel-air mixture entering the cylinder was measured immediately ahead of the intake valve, and the temperature of the preheated air was also measured at a point just before the position at which the fuel was injected. The exhaust temperature was taken immediately after the exhaust valve. All these measurements were taken with the aid of radiation-shielded thermocouples. Cylinder head temperatures were also measured by means of two small thermocouples, one placed close to the sparking plug and the other at a point diametrically opposite. The ignition timing was checked by means of a neon glow discharge lamp indicator mounted on the flywheel, with a metal contact strip placed close to the flywheel but insulated from the engine crankcase and connected to a sparking plug terminal only during the test.

## TEST RESULTS

The necessity of using a pick-up insensitive to the mechanical vibrations of the engine is shown by the results illustrated in Fig. 5. The detonation intensity of a single-cylinder aircraft test engine was determined as a function of the charging pressure, first using a pick-up of conventional design (Curve 1), and then by means of the two-diaphragm pick-up (Curve 2). The rather sharp increase in apparent detonation intensity shown by curve 1 is due to the increasing mechanical vibration of the cylinder head which increases with the combustion pressure and hence with the charging pressure. The discontinuity point corresponding to incipient detonation is at 14·2 kg/cm² on curve 2, instead of 14·7 kg/cm² as indicated by curve 1. Although the second pick-up had a vibrating mass 10 times smaller than that of pick-up No. 1, it is probable that its response was also slightly affected by mechanical vibration, possibly owing to the sliding occurring between the crystals. A pick-up completely insensitive to vibration would have given a constant reading up to the discontinuity point, as indicated by curve 3. Therefore, with a conventional type of pick-up having a relatively large mass and a low natural frequency, the point of incipient detonation is displaced to a pressure approximately 0·05 kg/cm² higher than the true value, and the slope is less pronounced, so that it becomes more difficult to determine the critical charging pressure accurately. This difficulty is even more apparent when

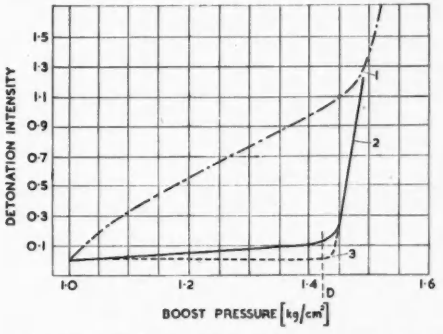



Fig. 5. **Detonation intensity plotted against charging pressure.**
(1) = curve obtained with conventional type of pick-up; (2) = curve with new improved pick-up; (3) = curve for pick-up with ideal response insensitive to mechanical vibrations of the engine.

taking measurements of the maximum rate of pressure rise for detonating and non-detonating combustion. The new pick-up and detonation meter can, however, measure low detonation intensities and will indicate incipient detonation before it becomes audible.

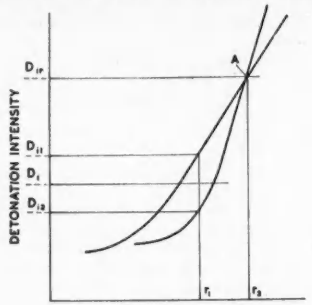



Fig. 6. **Detonation intensity curves of two fuels having the same octane rating in the C.F.R. engine but different detonation tendencies at low intensity levels.**

$D_{iF}$ = intensity used for C.F.R. rating ;
$D_i$ = allowable intensity under road conditions ;
$D_{i1}$, $D_{i2}$ = intensities actually obtained with fuels 1 and 2, respectively, under road conditions.

It has occasionally been noticed that under practical running conditions two fuels with the same octane rating may show different tendencies to detonate, as indicated by the curves of Fig. 6. The detonation intensity curves of the two fuels intersect at a point *A* corresponding to the high detonation intensity on which the octane rating is based using the C.F.R. engine. If the fuels are used at another compression ratio $r_1$, their detonation intensities will be different and one of the fuels may produce such heavy detonation that it may not be possible to use it in actual running. Conversely, it may occur that two fuels will have similar detonation properties under running conditions, although one of them may have a higher octane number.

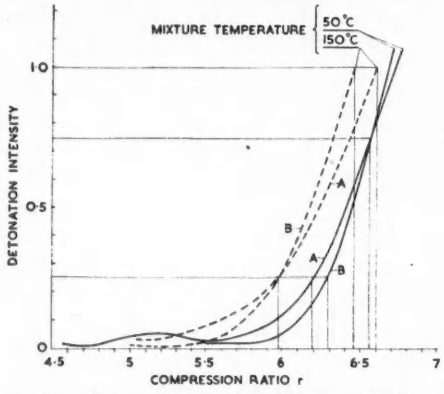



Fig. 7. **Intensity curves of two fuels A and B, with different octane ratings, at mixture temperatures of 150° and 50° C.**

Two sets of test curves of this type are shown in Fig. 7. Fuel *A* is a petrol, and fuel *B* a Swedish petrol-alcohol fuel blend containing 25 per cent alcohol. If the octane determination is made at 150° C intake temperature and at a detonation intensity of, for instance, 1·0, as in the case of the C.F.R. engine, then fuel *A* will receive a higher octane rating than fuel *B*, which is more sensitive than fuel *A* to an increase in compression ratio or charging pressure.

If the two fuels are used at an intake temperature of 60° C, with the same compression ratio of approximately 6 : 1 as previously, they will both give a low detonation intensity. However, on raising the compression ratio, audible detonation will first occur for fuel A, at a compression ratio of 6·2 : 1, and then for fuel B at 6·3 : 1, although according to the C.F.R. method the latter would have the lower octane rating.

Furthermore, if the octane rating is made with an intake temperature of 50° C and at low detonation intensity, fuel *B* will be rated approximately 1·5 units higher than fuel *A*. Under practical running conditions, with low intake temperature and on the border of audible knock, the rating of fuel *A* will thus be 1·5 octane units lower than that of fuel *B*, instead of being 1·5 units higher as indicated by the C.F.R. Motor method. It might be said, therefore, that in practical operation the rating of fuel *B* is 3 octane units higher than that indicated by the C.F.R. method.

The correlation is inadequate for various reasons. The laboratory rating in the C.F.R. engine is determined for a comparatively heavy detonation intensity, obtained by raising the compression ratio one unit above the value at which detonation just becomes audible, for instance, from 5 to 6. The road rating is made at the border of audible knock. The intensity levels are thus different and this causes discrepancies, since fuels with the same C.F.R. ratings can have different intensity curves, with slopes depending on the chemical constitution of the fuels, as shown in Fig. 7. The effects on detonation intensity of spark advance, mixture strength, and engine speed, also seem to depend on the nature of the fuel used.

It may thus be expected that octane ratings made at a high intensity level will differ from those made at a low intensity level if the nature of the unknown fuel is different from that of the reference fuel.

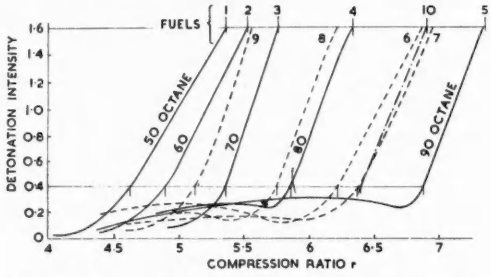



Fig. 8. **Detonation intensity curves for various reference fuels (solid lines) and tested fuels (dotted lines).**

Tests in a modified Delco-Light engine with low-pressure fuel injection. Running speed 900 rpm ; mixture strength chemically correct ; mixture temperature 50° C.

Fig. 8 shows intensity curves for five reference fuels (solid lines 1-5) with octane numbers 50, 60, 70, 80 and 90, and various tested fuels. The slope appears to vary according to the constitution of the fuel. This variation is particularly apparent in curves 6, 7, 2 and 9. On the basis of these results, the compression ratios corresponding to the detonation intensities 1·6 and 0·4 were determined for the reference fuels, and the curves of Fig. 9 were then drawn. These curves give the octane rating as a function of the compression ratio for high and low detonation intensities ($D_i$ = 1·6 and $D_i$ = 0·4).

By means of these two calibration curves, unknown fuels may be given equivalent ratings for high and low detonation intensities. The compression ratio at a given intensity level is first determined from a detonation intensity curve of the type shown in Fig. 8. The octane rating for this compression ratio and intensity level is then obtained from the calibration curves of Fig. 9.

For these tests, the operating conditions were as

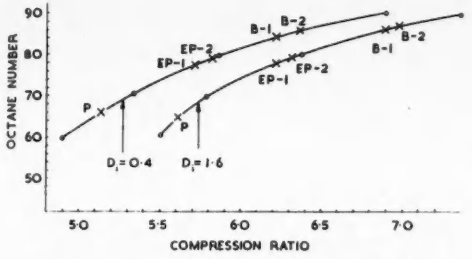



Fig. 9. **Calibration curves showing the relationship between the octane rating of the reference fuels and the compression ratio at two different intensity levels $D_i$ = 0·4 and $D_i$ = 1·6.** Symbols : ○ = reference fuels ; × = tested fuels ; P = petrol ; EP-1 and EP-2 = ethylized petrols I and II ; B-1 = "Bentyl" (75% petrol + 25% ethyl alcohol) ; B-2 = bentyl + 10% benzol.

follows :—Engine speed 900 rpm ; ignition timing 18° b. TDC; mixture temperature 50° C ; mixture ratio chemically correct. A summary of the results obtained is given in the following table (See caption of Fig. 9 for details of the fuels tested) :—

| Fuel No. | Designation | Octane rating at $Di$ = 0·4 | Octane rating at $Di$ = 1·6 | Octane rating by ASTM-CFR Motor method |
|---|---|---|---|---|
| 6 | B–1 | 84·5 | 86+ | 81 |
| 7 | B–2 | 86 | 87 | — |
| 8 | EP–1 | 78 | 78 | 78 |
| 8a | EP–2 | 80– | 80– | 80 |
| 9 | P | 66 | 64·5 | 67+ |

The two ethylized petrols 8 and 8a have the same octane ratings at both low and high detonation intensities and these ratings also agree with those obtained by the ASTM-CFR Motor method. Reference to Fig. 8 shows, however, that the intensity curves for fuels 8 (EP-1) and 4 (reference fuel 80 octane) were so alike as to be practically coincident, so that the same rating was obtained irrespective of detonation in the tests.

The octane ratings for fuels 9, 6 and 7 show greater deviations. Fuels 6 and 7, which contain alcohol and alcohol with benzene, respectively, are the kinds of fuel which usually receive higher ratings by the CFR Research method. For certain types of petrols, the CFR Motor method and the CFR Research method may give the same results, for instance, a straight-run petrol with a tetra-ethyl lead content of 0·8 cm³/litre is rated by both methods at 85 octane.

According to SINGER*, the difference in octane ratings by the Research and the Motor methods varies with the chemical constitution of the fuel, the Research method giving as a rule higher values, even for petrols with alcohol content and certain ethylized petrols. The difference in octane rating is nil or relatively small for straight-run petrols of paraffin or naphthene base (1-2 octane numbers), more appreciable for aromatic petrols (6-7 octane numbers) and greatest for cracked petrols (up to 10 octane numbers).

As previously mentioned in conjunction with the discussion of Fig. 7, it seems that the slope of the detonation intensity curve depends on the pressure and temperature conditions in the engine, and this applies also to the reference fuels. The octane rating of a fuel under altered operating conditions will not vary if the slopes of the intensity curves of the test fuel and the reference fuel are affected to the same degree.

If the variation of the operating conditions has a different effect on the slopes of the two curves under comparison, then the octane rating will be dependent on the operating conditions. Fuels with similar chemical constitutions will be similarly affected by changes in the

*See : B. Singer, *Oel u. Kohle*, Vol. 37, 1941, p. 798.

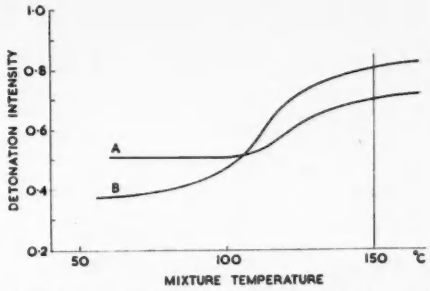



Fig. 10. **Curves for two fuels A and B, showing the effect of mixture temperature on detonation intensity at a constant compression ratio** $r$ = 6·3 : 1.

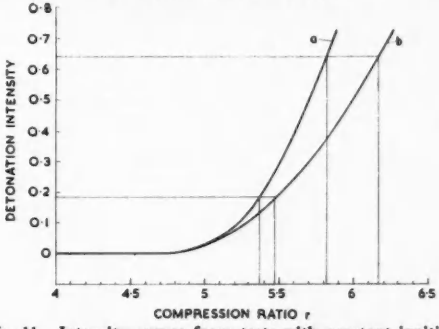



Fig. 11. **Intensity curves from tests with constant ignition timing (curve *b*) and with ignition timing increasing with the compression ratio (curve *a*).**

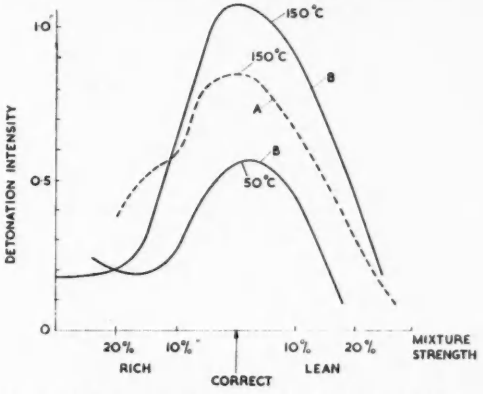



Fig. 12. **Influence of mixture strength on detonation intensity at a constant compression ratio for two fuels A and B having different octane ratings.**

For fuel *B* the measurements were made at two different mixture temperatures (50° and 150° C).

mixture temperature. However, if the chemical analyses of the fuels are different, the effect may be as illustrated in Fig. 10, that is, the two fuels will give the same detonation intensity at a given mixture temperature (about 110° C in the example considered), but one fuel (*B*) will have less tendency to detonate at lower temperatures, and a greater tendency at higher temperatures, than the other fuel (*A*).

The effect of ignition timing is shown in Fig. 11. Curve *b* is for a constant ignition timing of 18 deg. b. TDC, whereas curve *a* is obtained for an ignition

(*Concluded on page 70*)

RUSSIA

# Investigation into Automatic Three-Phase Arc-Welding

By G. P. MICHAILOV, B. S. BRIL and E. I. BOBROV. (From *Avtogenoe Delo*, No. 7, 1950, pp. 9-12, 8 illustrations.)

*A 3-phase arc-welding head developed in Russia is described in this article and the advantages of 3-phase welding are discussed. The conception of a "fusion coefficient" is introduced and the factors influencing this coefficient are enumerated.*

RESEARCH has proved considerable economic and technical advantages in 3-phase arc-welding. For experimental purposes, an automatic 3-phase high power welding head was developed for butt and angle welding under flux of straight and curved seams of any dimensions. It was found that greater thicknesses can be welded with the 3-phase arc and also that a greater depth of penetration is made possible.

The arc length is regulated automatically, i.e., the electrodes of 5, 6 or 8 mm diameter wire are fed at a constant speed adjustable between 0·33 and 9·7 fpm. The travel of the welding head along the seam is effected by means of an electrically driven carrier.

The maximum welding current is 2,500 amperes per phase. The angle between the electrodes is 36 or 45 degrees according to the type of nozzle used. The welding head weighs 100 lb including motor, reduction gear, feed mechanism and two nozzles.

In order to facilitate the determination of the welding efficiency with a 3-phase arc and to enable a comparison to be made with single-phase welding, calculations were based on a "fusion coefficient" expressed in ounces per ampere-hour. The determination of this coefficient, in the case of 3-phase arc-welding, is based on the total current in the two electrodes and is, therefore, not identical with the "fusion coefficient" for single-phase arcs.

The magnitude of the fusion coefficient for a single-phase arc depends on the arc current, arc voltage, diameter and composition of the electrode, and wire projection of the electrode wire beyond the nozzle, and on the type of flux used. In 3-phase welding, in addition to the above factors, the fusion coefficient is also influenced by the distance between the electrodes, the arrangement for switching on the source of current, and the welding speed.

The output and economy of automatic welding are determined by (a) the fusion of the two parent metal faces and (b) by electrode fusion. Hence, depending on the kind of steel to be welded and its thickness, the "total fusion coefficient" is of considerable interest, and this can be calculated from the formula :—

$$K = K_e + K_p = 3{\cdot}2\,\frac{F_d + F_p}{I_1 + I_2}\,v\,\gamma$$

where $K$ = total fusion coefficient [oz/Ah],
$K_e$ = fusion coefficient of electrode wires [oz/Ah],
$K_p$ = fusion coefficient of parent metal [oz/Ah],
$F_d$ = cross-sectional area of the metal deposited [sq in.],
$F_p$ = cross-sectional area of fused metal [sq in.]
$v$ = welding speed (fpm),
$\gamma$ = specific weight of the welded seam [lb/in³],
$I_1 + I_2$ = total current in electrodes [A].

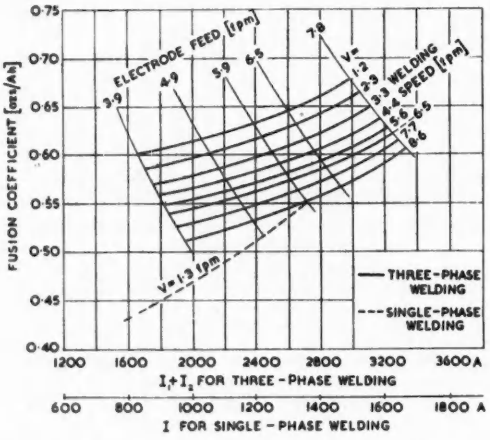



Fig. 1. **Relation between fusion coefficient and total current in electrodes at various welding speeds, for three- and single-phase welding.**

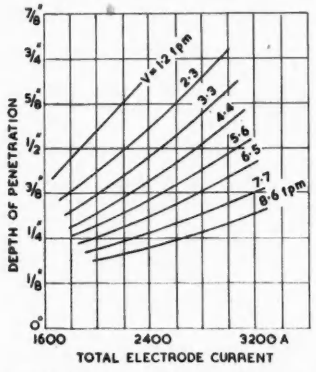



Fig. 2. **Relation between depth of penetration and total current in electrodes at various welding speeds.**

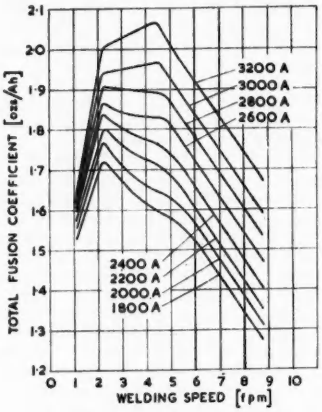



Fig. 3. **Dependence of total fusion coefficient on welding speed and current.**

A large number of tests, under laboratory conditions, was carried out to determine the above relation. During all experiments, the angle between the electrodes was kept at 36 degrees, the distance of projection of the

electrode wire beyond the contact part of the nozzle was 2 in., and the distance between the electrode ends was ½ in. Welding speeds varied between 1·2 and 8·6 fpm while the electrodes were fed at speeds between 3·9 and 7·8 fpm, which corresponds to a variation of current in the electrode from 800 to 1600A. In all cases, the arc was kept within 32 to 34V by varying the inductance of the coils.

An analysis of the results gives the following conclusions :—By increasing the welding speed from about 1 to 9 fpm, the fusion coefficient decreases by 10 to 15 per cent, see Fig.1. There is reason to believe that, with increasing welding speed, the rate at which energy is supplied for melting the electrode wire decreases, whereas the rate at which energy is given up for fusing the welded metal increases. The dependence of the fusion coefficient on the current is obvious.

For the cases under investigation, the fusion coefficient varied from 0·5 to 0·68 oz/Ah and the output of the head from 56 to 126 lb/hr, depending on current and welding speed. The increase of output for 3-phase welding as compared with single-phase welding, for the same values of electrode current, is as much as 2·1 to 2·7.

The depth of penetration also depends greatly on the current and welding speed, see Fig. 2. The depth of penetration increases more rapidly for small and medium currents with decreasing welding speed, whilst with higher currents it increases with falling welding speeds down to 22 fpm, beyond which speed it decreases. The cross-section of the weld also grows with increasing current, and it decreases with increasing welding speed.

The total fusion coefficient varied from 1·27 to 2·07 oz/Ah, its dependence upon welding speed and current being illustrated in Fig. 3.

Micro-examination of the 3-phase weld showed that for welding speeds up to 4·4 fpm and higher, the overheated zone is either absent or very small with comparatively fine grain size, and only in a few cases showed traces of Widmanstätten structure. The possibility of heat transfer from arc to electrodes and stock makes this method suitable for both thick and thin plates.

SWEDEN

# Statistical Aspects of Fatigue Strength

By W. WEIBULL. (From *Teknisk Tidskrift*, Vol. 80, No. 42, November 18, 1950, pp. 1059-1064, 9 illustrations.)

*This article gives full details of a new method for determining the fatigue strength of specimens of a given material. The "probability of rupture" is introduced as a new parameter in the S-N diagrams and used to determine the region within which the probability of fracture is zero. Test results are evaluated and test curves are compared with curves based on theoretical formulae.*

THE fatigue strength of a specimen is based on the number $N$ of load reversals the specimen can withstand before rupture when subjected to a given stress $S$. The life $N$ of the specimen is not only dependent on the applied load, but also on other factors, such as the type of material, its structure, internal stresses, geometrical shape and dimensions, surface properties, the ambient air, and other, as yet unknown, factors. Thus, it frequently happens that although tests are made under what are regarded as identical conditions, the $N$ values for various specimens show a considerable amount of scatter.

## THE *P-S-N* DIAGRAM

It is, therefore, necessary to have recourse to further statistical analysis, and to introduce a new parameter, viz., the "probability of rupture" $P$. This will be defined as the ratio of the number of ruptured specimens after $N$ reversals, to the total number of specimens tested, at a given stress $S$.

This ratio can be determined experimentally, and the results are then plotted as $P$-curves in a $P$-$S$-$N$ diagram, as shown in Fig. 1. In this figure, based on tests of 9 specimens for each stress value, $P = 0{\cdot}1$ is the curve connecting the first specimens ruptured at each given stress, $P = 0{\cdot}2$ being the curve connecting the second test specimens ruptured, etc. $\overline{S}_m$ is the mean rupturing stress, determined as the mean height of the family of $P$ curves at the position at which they have a horizontal tangent, and $\overline{S}_u$ is the stress value at which the probability of rupture is zero for the entire range considered.

In certain cases, a complete $P$-$S$-$N$ diagram is not required. It is sometimes regarded as sufficient to determine one $S$-$N$ curve, for instance the curve for $P = 0{\cdot}5$, and to indicate the spread of the $N$-values for different stress values.

A method which is frequently employed, although it gives very unsatisfactory results, is to use the test data available to construct one $S$-$N$ diagram consisting of two straight lines, one inclined at a given angle and the other horizontal, without any indication of the spread.

The only possible way of obtaining the complete diagram experimentally is to take a sufficiently large number of specimens and an adequate number of stress values. The final vertical intersection may be determined experimentally without extrapolation as the rupturing stress for $\log N = 0$ (i.e., for $N = 1$) or, more accurately, for $n = 1/4$, which corresponds to the static strength of the specimens. However, it should be emphasised that these static values should be deter-

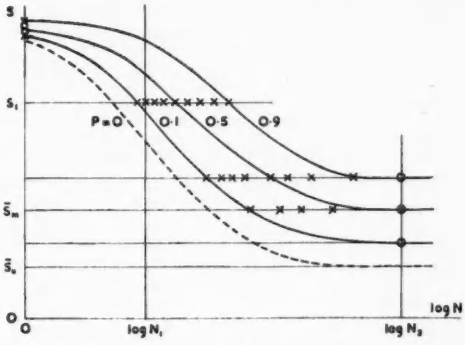



**Fig. 1. Curves through test points, showing relationship between stress $S$ and life $N$ for different values of the probability of rupture $P$.**

mined using the same loading arrangement and the same type of specimens as for the fatigue tests. Results obtained with ordinary tensile testing machines should only be used in exceptional cases.

It is essential to have a sufficient number of test specimens for all the loads considered, since only under these conditions will it be possible to determine the different $P$-curves without interpolation. If, for instance, 9 specimens are available for each load, as shown in Fig. 1, the lowest value of log $N$ for the various $S$-values will most probably be situated on the curve $P = 0{\cdot}1$, and the highest value on the curve $P = 0{\cdot}9$, etc.

Therefore, in order to obtain the probability curve for $P = 0{\cdot}01$ without extrapolation, 99 test specimens would be required for each load value. The curve $P = 0$ would thus necessitate testing an infinite number of specimens, so that in practice this curve can only be obtained by extrapolation from values determined under identical conditions. The $P = 0$ curve may be determined either graphically or analytically. In the latter case, it is necessary to determine first the distribution function for $S$ and the $P$-$S$ relationship, or the distribution function for $N$ and the $P$-$N$ relationship, using parameters based on the test results.

## EVALUATION OF TEST RESULTS

The evaluation of a series of tests will now be considered for the usual case where the tests have been made with only a very limited number of specimens. Moreover, various equations will be derived for the determination of the probability curves, but it cannot be said with certainty whether these equations will be directly applicable to all other types of materials or loading conditions. The entire programme of tests and the type of tests to be carried out depend, therefore, on whether or not adequate values can be obtained for the determination of the parameters occurring in the equations.

The method of investigation will now be illustrated by means of data from bending fatigue tests made on specimens of Bofors steel FR-86, oil-hardened at 850° C and annealed to a Vickers hardness of approximately 255. The test specimens were 8·00 mm in diameter and were carefully polished. Using 111 specimens altogether, 3 specimens were tested at the maximum stress of 84·5 kg/mm² and 9 specimens were tested at each of the 12 different loads between 75 and 40 kg/mm², with a maximum number of 10 million load reversals per specimen. Fracture occurred in all cases, with the exception of two specimens tested at the lowest stress values. The test results were first tabulated as indicated below :—

TABLE I.—STATISTICAL PARAMETERS FOR log $N$. ROTARY BENDING TESTS ON SPECIMENS OF BOFORS STEEL FR-86.

| Stress $\pm S$ kg/mm² | No. of specimens | $\log_{10} N$ Median value | $\log_{10} N$ Mean value | $\log_{10} N$ Mean deviation $\sigma$ | $\log_{10} N$ 1/3 of variation width | Correlation between log $N$ and $H_v$ | Values reduced to $H_v = 255$ Mean dev. $\sigma$ | Values reduced to $H_v = 255$ 1/3 of variation width |
|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| 84·5 | 3 | 0 | 0 | — | — | — | — | — |
| 75 | 9 | 3·38 | 3·38 | 0·06 | 0·06 | + 0·73 | 0·04 | 0·04 |
| 70 | 9 | 3·88 | 3·84 | 0·18 | 0·16 | + 0·49 | 0·15 | 0·16 |
| .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 42 | 9 | 6·05 | 6·02 | 0·21 | 0·23 | — 0·25 | 0·21 | 0·23 |
| 40 | 9 | 6·66 | — | — | — | — | — | — |

It was found that the mean deviation $\sigma$ was very small for $S = 75$, but no other tests reached this low value. The variation width was very nearly equal to $3\sigma$. Furthermore, the region within the limits $\pm 1{\cdot}5\sigma$ includes 80 per cent of all the values. For a normal distribution, the figure should be 86·6 per cent, which shows that the log $N$ distribution is fairly symmetrical but not a normal distribution. Column (7) shows the correlation between log $N$ and the Vickers hardness number $H_v$, measured on the largest diameter of the specimens. The correlation was found to be positive for all loads above 46 kg/mm². Some of the values were not significant, owing to the small number of specimens, but the positive correlation is beyond doubt for loads exceeding 46 kg/mm².

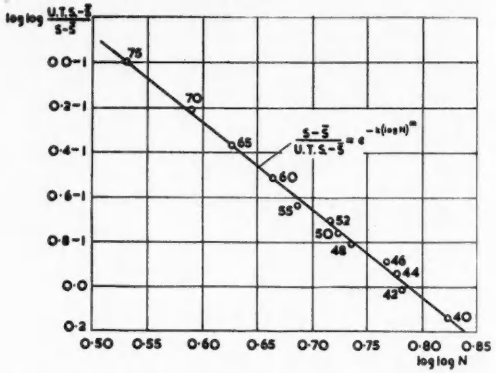



Fig. 2. $S$-$N$ relationship for $P = 0{\cdot}5$ for rotary bending tests on Bofors steel FR-86.
$U.T.S. = 84{\cdot}5$ kg/mm², $\bar{S} = 38{\cdot}0$ kg/mm², $k = 0{\cdot}000363$, $m = 3{\cdot}91$.

Calculating backwards, one can determine the influence of hardness on the life of the specimen and then eliminate the variations in hardness by reducing all log $N$ values to the same hardness number, in this case $H_v = 255$. By means of this correction, the hardness effect is converted from an unknown factor into an at least partly known factor, with the result that the scatter of the log $N$ values is reduced, as evidenced by the values shown in columns (5) and (8). The influence of other factors can be eliminated in a similar manner where required. In preparing a programme of tests, it is, therefore, necessary to determine beforehand the requirements to be fulfilled in order to obtain a given accuracy in the results, using the smallest possible number of specimens, tested with a minimum number of load reversals.

## EXTRAPOLATION FOR $N \to \infty$

The test results plotted in the $S$-$N$ diagram will now be extrapolated to obtain the limiting values for $P = 0$ and $N = \infty$. In a previous article by the author[1] it was shown that the following equation :—

$$N = A\,(S - \bar{S})^m \quad .. \quad (1)$$

applies for the test values obtained by RAVILLY. This equation can be used as an extrapolation formula for large $N$-values. It is conceivable that it should be possible to approximate the $S$-$N$ curves in the region of large $N$-values by means of two or three straight lines, since discontinuities are physically unlikely to occur.

A private communication received from E. EPREMIAN of the Metals Research Laboratory, Pittsburgh, Penn., U.S.A., indicates that it is possible to obtain a very satisfactory representation of a test series published by WÅLLGREN, by means of the following equation :—

$$(S - \bar{S})/(U.T.S. - \bar{S}) = 1 - \Phi\,(a \log N + c) \quad (2)$$

The left-hand side of this equation represents the

" normalised " stress, where $\bar{S} = 0$ when $S$ = measurement limit, and $U.T.S.$ = 100 per cent when $S$ = tensile strength value. The symbol $\Phi$ denotes the Gaussian error function, $a$ and $c$ being parameters.

To avoid using the Gaussian function, which requires reference to tables, it is suggested modifying the above equation so that

$$(S - \bar{S})/(U.T.S. - \bar{S}) = e^{-k(\log N)^m} \quad .. \quad (3)$$

Eq. (1) is then a special case of eq. (3), obtained by putting $m = 1$. The term $U.T.S.$ can be regarded as a parameter which is not necessarily equal to the tensile strength.

Substituting in eq. (3) the median values taken from Table I, we obtain the curve for $P = 0{\cdot}5$ shown in Fig. 2, which becomes a straight line when using suitable loglog co-ordinates. The value of $U.T.S.$ = 84·5 kg/mm² is that obtained in a normal tensile test. It is readily seen that none of the parameters has a value greater than that of the tensile strength. Similar straight lines are also obtained for other values of $P$ for the Bofors steel specimens under consideration, and for the test results of WÅLLGREN previously mentioned. The agreement of the straight line with the WÅLLGREN results is even better than in the case of the Bofors specimens, and this may be due to the fact that the rectangular section test specimens used by this investigator were hollow sections designed to produce stress concentration.

Table II shows a comparison between measured and calculated values of log $N$, using eq. (3) and the parameter values given in Table I.

TABLE II.—MEASURED AND CALCULATED VALUES OF log $N$ FOR ROTARY BENDING TESTS OF SPECIMENS OF BOFORS STEEL FR-86.

($U.T.S.$ = 84·5 kg/mm²; $\bar{S}_1 = 36{\cdot}0$, $\bar{S}_2 = 38{\cdot}0$, $\bar{S}_3 = 39{\cdot}0$; $k = 0{\cdot}000363$; $m_1 = 4{\cdot}0$, $m_2 = 3{\cdot}91$, $m_3 = 3{\cdot}86$.)

| $\pm S$ kg/mm² | $P = 0{\cdot}1$ log $N$ meas. | calc. | $P = 0{\cdot}5$ log $N$ meas. | calc. | $P = 0{\cdot}8$ log $N$ meas. | calc. |
|---|---|---|---|---|---|---|
| 75 | 3·29 | 3·27 | 3·38 | 3·39 | 3·46 | 3·47 |
| 70 | 3·57 | 3·68 | 3·87 | 3·84 | 4·05 | 3·94 |
| 65 | 4·00 | 4·05 | 4·26 | 4·23 | 4·76 | 4·35 |
| 60 | 4·20 | 4·37 | 4·61 | 4·59 | 4·90 | 4·73 |
| 55 | 4·76 | 4·70 | 4·87 | 4·95 | 5·12 | 5·12 |
| .. | .. | .. | .. | .. | .. | .. |
| 42 | 5·71 | 5·74 | 6·05 | 6·21 | 6·39 | 6·56 |
| 40 | 5·97 | 6·00 | 6·66 | 6·63 | — | — |

This table shows that close agreement is obtained between measured results and the values calculated from the above equations. Thus, the agreement is not due to the use of the loglog scale as shown in Fig. 2. This fact is further illustrated in Fig. 3, which shows calculated curves and measured results for the Bofors specimens, in the form of an $S$ — log $N$ diagram. The range covered in the horizontal direction is from 0·50 — 0·84 in the first case, and 0 — 10·0 in the second. The corresponding measurement points are shown in both diagrams on either side of the theoretical curves, and the deviations are not eliminated by the loglog scale used. The practical advantages of the diagram of Fig. 2 are easily appreciated:—the $P$-curves are represented as straight lines which can be determined by calculation after evaluating the corresponding parameters $k$ and $m$, and the method of least squares can be applied directly.

## EXTRAPOLATION FOR $P \to 0$

The $S$-$N$ field can be expanded up to the limit $P = 0$ by extrapolation either in the horizontal or in the vertical direction.

The first alternative requires the use of a distribution

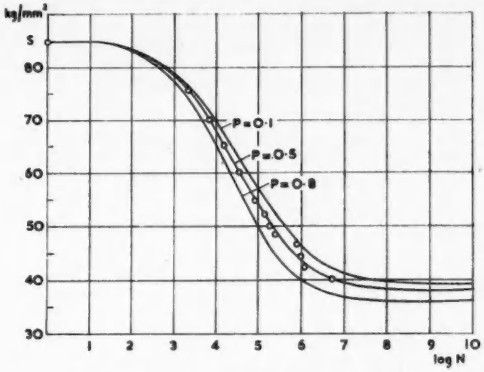



Fig. 3. **Test curves for Bofors steel FR-86.**

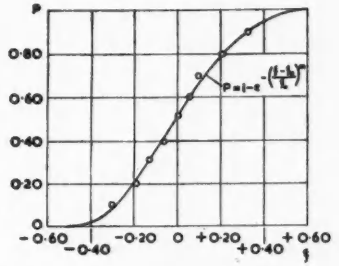



Fig. 4. **$\xi - P$ relationship for Bofors steel FR-86.** $\xi_u = -0{\cdot}50$, $\xi_0 = +0{\cdot}57$, $m = 2{\cdot}413$.

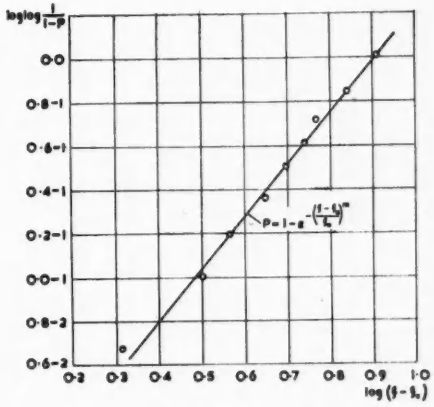



Fig. 5. **Distribution of $\xi$ for rotary bending tests of Bofors steel FR-86.** $\xi_u = -0{\cdot}50$, $\xi_0 = +0{\cdot}57$, $m = 2{\cdot}413$.

function adequately representing log $N$. We may try using the expression:—

$$P = 1 - c^{-\left(\frac{\xi - \xi_u}{\xi_0}\right)^m} \quad .. \quad (4)$$

where $\xi = x - \bar{x}$ = deviation from the mean value $\bar{x} = \overline{\log N}$ for each stress value $S$, and $x = \log N$. As it is certainly not absolutely correct to assume that the loads have no effect on the spread of the curves, sufficient

measurements have been taken to show the accuracy of this formula.

The results are illustrated in Figs. 4 and 5. The calculated value of $\xi_u = -0{\cdot}5$ shows that the curve $P = 0$ follows the curve $P = 0{\cdot}5$ at a distance of 0·50 in the log $N$ scale.

For the other alternative, extrapolation in the vertical direction, we may use the same distribution function as above, that is, eq. (4), and apply it to the test results given by EPREMIAN and reproduced in Table III:—

TABLE III.—RESULTS OF ROTARY BENDING TESTS WITH STEEL SAE 1050.

| Stress, psi | No. of fractures | Total No. of specimens |
|---|---|---|
| 43,000 | 20 | 20 |
| 42,500 | 19 | 20 |
| 42,000 | 16 | 18 |
| 41,500 | 13 | 20 |
| 41,000 | 14 | 21 |
| 40,500 | 8 | 21 |
| 40,000 | 4 | 17 |

The results are shown in Fig. 6. The calculated value for the lower limit is $S_u = 37{,}000$ psi, which indicates that no fractures can occur below this value, although this is an approximate figure based on the small number of specimens tested. Nevertheless, these tests took a considerable time, since they correspond to a total of some 3,000 million load reversals. The tests were carried out up to a value of $N_{max} = 50$ million reversals, and the results for the large $N$-values can, therefore, be regarded as showing very little deviation from the values for $N \to \infty$. All the other points of

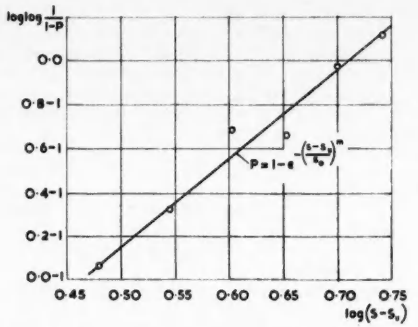



Fig. 6. **Distribution of measurement limits with steels SAE 1050 for rotary bending tests.**
$N = 50 \times 10^6$, $S_u = 37{,}000$ psi, $m = 4{\cdot}00$. (After E. Epremian.)

the curve $P = 0$ can be obtained in the same manner.

It has thus been shown that there are two possible methods for the determination of the curve for $P = 0$. It is not possible as yet, on the basis of the limited amount of experimental material at present available, to say which is the better method.

BIBLIOGRAPHY.

[1] WEIBULL, W. A.: Statistical representation of fatigue failures in solids. *K.T.H. Handl.*, No. 27, 1949.

[2] WÄLLGREN, G.: Fatigue tests with stress cycles of varying amplitude. *Flygtekn. Försöksanst. Medd.*, No. 28, 1949.

U.S.A.

# Automatic Self-Centring Rolls and Pulleys

By E. T. LORIG. (From *Iron and Steel Engineer*, Vol. 27, No. 11, November, 1950, pp. 57-67, 10 illustrations.)

*The tracking and aligning problems encountered in the processing of cold wide light-gauge flat metal strip in continuous lines for pickling, cleaning, shearing, electrolytic tinning, continuous galvanising, etc., have never been fully solved. In view of the increasing emphasis on continuous processes, great importance is attached to the self-centring roll described in this article. It has previously been referred to in The Blue Pages of our October, 1950, issue.*

BEFORE proceeding with a description of the action of self-centring rolls, it may be helpful to state the conclusions reached from a study of the reactions that take place in passing strip over conventional continuous-bodied rolls.

Continuous-bodied crowned rolls have very little power in themselves to maintain metal strip centred and in alignment on the centre pass line of such rolls. With such crowned rolls, a constant change in temporary straining of the strip from edge to edge takes place, which represents the major factor in securing re-centring and alignment. It becomes evident, therefore, that both the positioning of the rotating roll planes at the surface of all types of rolls and the positioning of the longitudinal planes in the moving strip approaching and in arced contact with the roll surfaces are predominant factors and alone determine the path that a continuous light-gauge metal strip section under tension will take in passing over a series of rolls consecutively without side guides. Guides have proved to be detrimental to good operations when in contact with metal strip edges under tension.

It becomes evident, also, that automatic changes in positioning of the moving strip, or both, were the factors requiring investigation to improve tracking and aligning of the strip edges and centreline over a series of rolls or pulleys.

Because of the fact that the planar action at the surface of each rotating conventional roll, in a series of such rolls being utilised for forwarding continuous strip under tension, is rectilinear with all rotating roll planes in parallelism (but not necessarily completely parallel with those in adjacent consecutive rolls in the series), variable strip deformation from edge to edge alone does the work of re-centring and aligning.

The high strip tensions now being employed to secure sufficient deformation in the strip to maintain fairly good tracking indicates that nothing further can be done with continuous-bodied rolls to improve this situation regardless of shell thickness or shape. In fact, the extent of this deformation should be reduced, if at all possible, by somehow providing automatic means for lowering strip tensions and, at the same time, for improving tracking more naturally to avoid the

danger of over-straining the strip, which at times results in edge waves, damaged strip, and lack of strip flatness at the delivery end of processing lines or in metal strip conveyors.

## DEVELOPMENT OF AUTOMATIC SELF-CENTRING ROLLS

A further study of the planar action at the surfaces of the rolls indicated that the best possible means of securing the proper data for obtaining most of the desired results would be to construct unconventional model rolls, for trial and experiment, in which the planes in each half of each roll rotating on or with a common axle or shaft would rotate slightly out of parallelism with the planes of the other half in a specific manner.

It had been determined that the parallel planes perpendicular to the roll axes and intersecting rotating conventional rolls at their contacting surfaces, and those intersecting the contacting surface of the longitudinally moving strip arced over the rolls, always remain parallel and in exact alignment one with the other, creating a longitudinal moving parallel force combination so powerful that the rolls and contacting strip refuse to have their combination of parallelism and alignment disturbed by external lateral forces applied to the strip. Only temporary or permanent distortion of the metal in the strip passing between and over such rolls can change the vertical positioning of the planes in the strip with respect to its edges, but all rotating roll planes in the arced section of strip passing over the rolls still remain in parallelism and in exact alignment one with the other, presenting a formidable force combination most difficult to deal with under reasonably low strip tensions, and resulting low surface pressures between moving strip and roll bodies.

If the rotating roll parallel planes in each half of each roll in a conveying system or processing line are thrown out of parallelism with those of the other half as mentioned above, then the two groups of parallel planes created in each roll rotate at definite angles on each side of the transverse vertical centreline of the roll in directions which are independent and out of alignment with each other. Such unconventional rolls, when properly constructed, not only have the ability to rotate on their common axis with their two groups of planes rotating at an angle with each other, but will each rotate at an angle with the parallel planes in the arced strip in contact with the roll, in which strip the planes remain parallel over the full width.

Thus, in this combination of rotating roll and arced strip in contact being forwarded, we have a system of conveying in which three separate groups of parallel planes are active, no single group of which can normally be parallel to either of the other two.

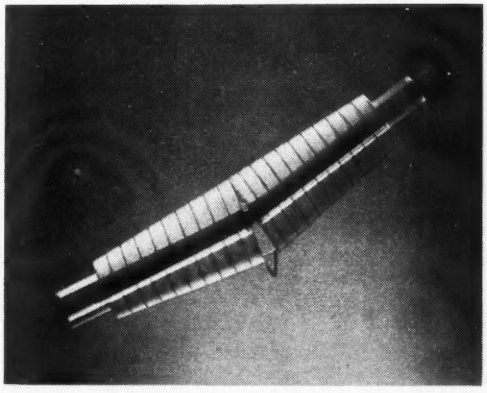


Fig. 1. **Transparent model of self-centring automatic roll.**

## FUNCTIONING OF AUTOMATIC SELF-CENTRING ROLLS

Thus, the unconventional split double conical roll or pulley known as the " automatic self-centring roll " came into being (see Fig. 1), which, when used singly in connection with certain applications, or in series to form belted or processing line applications, has remarkable strip centring, tracking and aligning abilities for practically every kind of flat strip being processed or utilised in conveyor belt systems, metallic or otherwise.

When rotating a series of these unconventional rolls with any and all types of objects to be conveyed by surface contact, natural strongly opposed lateral frictional forces are released on the roll surfaces tending to move objects in contact toward the transverse roll centres into a position such that the centre of gravity of the objects always remains on the centre pass line while being forwarded, in which position the natural opposed lateral frictional forces are in constant balance.

When external forces utilised to displace objects from their pass line are released, objects again return to this pass line, and if the objects are sufficiently long and in contact with a sufficient number of the rolls, automatic alignment as well as automatic centring will take place.

Metal belts, or any type of belt for that matter, forming a closed circuit making repetitive cycles can be operated over self-centring pulleys under any tension and linear speed with great exactness. Load distribution over the width of metal conveyor belts, for instance, will affect positioning of the belt on the pulleys for the reason that self-centring pulleys operate on the principle of centring combined cross-sectional centre of gravity of the belt and live load being forwarded.

Continuous metal strip being forwarded over a series of self-centring rolls under tension in a processing line presents a somewhat different problem. If the strip is straight, no problem exists and the strip will remain centred and in alignment regardless of tension applied throughout the length of the line, if the rolls are reasonably maintained in parallelism and alignment. If, however, considerable camber or crookedness in the strip exists, then the pressure against the roll bodies becomes variable from edge to edge, which is, of course, the same as changing the centre of gravity of the cross-sectional area of the live load on the rolls. This will cause some movement laterally off the centre pass line until the opposed lateral frictional forces released in the unconventional self-centring rolls become balanced. Means have been developed, however, in the construction of pivoted automatic self-centring pinch rolls, which, when properly utilised in continuous lines, will cause the strip under tension to vary little from the centre pass line of the strip processing unit.

Metal strip processing lines equipped throughout with self-centring rolls and with pivoted automatic self-centring pinch rolls properly located in the line have the ability to dampen out errors in strip alignment as the strip proceeds through the line regardless of camber.

## ACTION OF METAL STRIP IN CONTACT WITH ROLLS

Figure 2 shows two cylindrical rolls in parallelism and alignment, over which a length of straight metal strip is highly tensioned in an off-centre position and in an unrestricted manner. As the strip is forwarded, thereby rotating both rolls, the strip will continue to

move laterally away from the pass line ultimately fouling its edge on the roll-supporting framework.

The reason for this lateral movement is as follows: Once the strip under tension is off centre of the pass line, then the resultant mean contact pressures between rolls and strip are off centre in the same direction. Therefore, the reactive pressure at the roll bearings and support nearest the mean contact pressures between rolls and strip must increase while those on the opposite end must be reduced as the strip moves laterally. All materials in the assembly shown have resilience under load. The magnitude of deflection, linear extension and contraction, secured because of this resilience in any object, increase and decrease in proportion to the load applied and are variable within the object, depending upon the load distribution and the location of the reactions resisting movement of the load.

The variable factors of deflection, linear extension and contraction in the materials which would be utilised to construct the supports and rolls subjected to high strip tensions may be very minute and practically infinitesimal as the strip moves laterally off centre. A fraction of 0·001 in. differential in contraction and extension between $R_1'$ $R_2'$ and $R_1''$ $R_2''$—Fig. 2, for instance, is sufficient movement (caused by the resilience in the bearing supports and framework) to throw both rolls 1 and 2 out of parallelism an unmeasurable amount, but sufficient to cause continued lateral movement of the strip away from the centre pass line. In Fig. 2, therefore, the relative planar action between the two rolls is always prone to change in accordance with the varying position of the strip, and since the low stretchability in the strip does not permit of sufficient temporary distortion on the approach side of the rolls to have the edges lie in planes exactly parallel or opposedly angled to those in the rotating rolls, no counteracting force is present to prevent the strip from continuing to move laterally away from the centre pass line. The above is also true of flat belts operating over a pair of cylindrical pulleys.

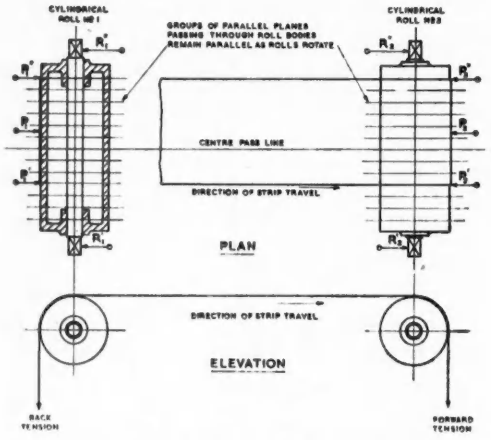



Fig. 2. **Behaviour of metal strip under tension when passing over uncrowned cylindrical rolls.**

Fig. 3 shows two rather heavily crowned rolls in parallelism and alignment, over which a length of straight metal strip is highly tensioned in the manner shown in Fig. 2.

All remarks and statements made above in connection with Fig. 2 also apply to Fig. 3, except those with reference to the strip and belt.

Crowning of the rolls does not change their planar action, and such rolls in themselves have no ability to centre the strip other than to assist in securing realignment. Crowning does, however, permit temporary deformation and distortion in the strip in a proper manner to allow the strip to return itself to the centre pass line.

It should be recognised, however, that in actual practice sufficient crown cannot be made available to secure accurate tracking of steel strip at all times; that if adequate crowning were used, permanent distortion would at times be encountered.

Concaving of the rolls does not change their planar action in that the strip is quickly distorted by moving off the centre pass line rapidly in either direction, and will continue to move in the same lateral direction when once started until failure of one edge or the other takes place.

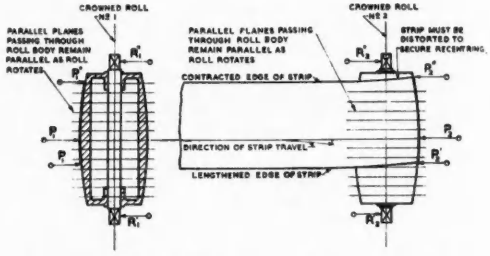

CROWNED ROLL NO 1
PARALLEL PLANES PASSING THROUGH ROLL BODY REMAIN PARALLEL AS ROLL ROTATES
CROWNED ROLL NO 2
PARALLEL PLANES PASSING THROUGH ROLL BODY REMAIN PARALLEL AS ROLL ROTATES
STRIP MUST BE DISTORTED TO SECURE RECENTRING
CONTRACTED EDGE OF STRIP
DIRECTION OF STRIP TRAVEL
LENGTHENED EDGE OF STRIP

Fig. 3. **Behaviour of metal strip under tension when passing over crowned rolls.**

The reason for this unidirectional lateral movement is that the metal is constantly distorted laterally in the wrong direction by the tension applied, causing the edges of the strip to lie in vertical planes that are inclined with respect to the rotating roll planes in a manner opposite to those encountered when distorting the strip over crowned rolls.

Fig. 4 diagrammatically shows two unconventional split type automatic self-centring rolls in their simplest form, over which a section of straight metal strip is tensioned in an off-centre position similar to that in Figs. 2 and 3.

The conical effect is greatly exaggerated for the sake of clarity in presentation. In actual practice, the conical or crowning effect required for the rolls can be as little as one sixtieth of that required for conventional crowned rolls.

The rectilinear action of the conventional rotating roll planes at the contacting surface of the strip presents

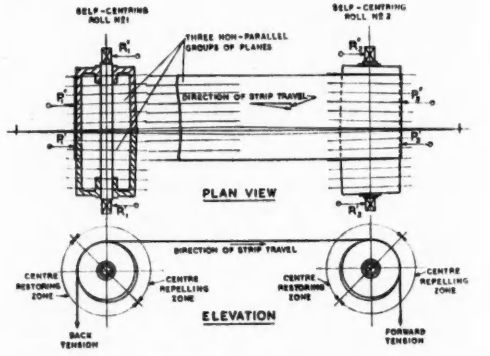



Fig. 4. **Behaviour of metal strip under tension when passing over automatic self-centring roll.**

a formidable rectilinear force combination that refuses to be disturbed readily when the strip is under tension. The two groups of planes, one at the surface of the rolls and the other at the contacting surface of the strip, always insist upon remaining in exact parallelism and in exact alignment, thereby regulating the directional tendency or course that the strip takes in passing over the rolls regardless of the direction in which the strip edges will be forwarded, and which can be markedly out of alignment with the unidirectional planes in the arced section of strip passing over the rolls.

In splitting the rolls as shown in Fig. 4, three groups of parallel planes intersecting the roll and strip surfaces are immediately formed, no group of which can normally be in parallelism or alignment with either of the other groups when the strip is being forwarded in contact with the rotating rolls.

Neglecting the functioning of the conical or crowning effect on the roll surfaces for the moment, each individual group of planes of the three in action has its particular function to perform in centring the strip on the centre pass line of the rolls.

1. The parallel planes intersecting at the surface of one-half of the roll, on which the major portion of the strip rests, always causes the frictional force between roll surface and strip simultaneously to move the strip both longitudinally and laterally toward the centre pass line of the two rolls.

2. The parallel planes intersecting the surface of the other half of the roll, on which the minor portion of the strip rests, tends to do likewise, except that the lateral component of force is in the opposite direction and is of a smaller magnitude.

3. The unidirectional planes at the strip surface which is in frictional contact with the rolls at the initial line of contact, being parallel over the full width of the strip, regulate positioning of the strip edges on the approach side of the rolls relative to that of the centre pass line.

With the strip off the centre pass line as shown in Fig. 4, and with a relatively light tension applied to the strip to secure motivation, the frictional forces between roll and strip surfaces on each side of the centre pass line are obviously out of balance. As the strip moves forward and the rolls rotate, the half of the split roll normally exposed to the greatest frictional area of contact will move the centre line of the strip laterally toward the centre pass line until all frictional contact forces are in balance.

This balance of forces can only be satisfied when the edge of the strip become closely equidistant from the centre pass line of the two rolls and when the strip becomes centred on that line.

There are factors such as camber, misalignment of rolls, concentrated localised tension in the body of the strip, unequal load of distribution under tensions that are too low in conveyor belts, etc., which can upset the centring action somewhat, but the lateral frictional forces released by splitting the rolls are constantly striving to centre the strip or belt.

In the above statements, the advantages of conical or crowning effect on the surface of the rolls has not been referred to, as the author wished to bring out the fact that centring of the strip or belt can, with automatic self-centring rolls, be secured in a relatively satisfactory manner by means of the lateral frictional forces released in splitting the rolls.

A slight conical effect on the surface of the rolls, far less than required with conventional rolls, is, however, of advantage, as aligning and re-aligning of the strip or belt on the centre pass line is more rapidly accomplished.

The relationship existing between the magnitude of strip deformation under tension, caused by providing a slight conical effect in each roll half, and the planar action at the surface of the split rolls, which releases the lateral components of frictional force to cause centring and tracking, is rather flexible and can be regulated in the design of such rolls for particular applications. Optimum conditions can be incorporated in the strip passing over the conical roll surface well within the elastic limit of the metal.

The angularity between the planes of both roll halves may be relatively great, say, a fraction of a degree, to secure required rapid re-centring per foot of strip travel. For metal conveyor belts making many repetitive cycles in a given time, however, this angularity should be very small, perhaps a fraction of a minute, with a corresponding reduction in conical effect on the surface of the automatic self-centring pulleys used. In the latter case, re-centring is accomplished much more slowly, but when the metal conveyor belt finally reaches the centre pass line of the two pulleys, the belt will remain there and continue to complete cycle after cycle with no perceptible variation of the centre pass line.

Fig. 5 diagrammatically shows an elevation of two automatic self-centring pulleys, over which a horizontal metal conveyor or power transmission belt is tensioned. Under static conditions involving no longitudinal movement of the belt and no rotation of the pulleys, the initial tensioning of the belt, which need not be high, together with the weight of the pulleys and belt will deflect the pulleys downwardly and inwardly toward the axes of the pulleys a slight amount, until the line of minimum conical effect at the roll surface in contact with the belt assumes a definite position when all static forces applied to the system are in balance. For the belted system shown in Fig. 5, this line of minimum conical effect always lies somewhere in a single quadrant of the pulleys' cross-sectional area where the belt is in contact. For very low belt tensions under static conditions, this line lies at point *A* on either pulley, and as the belt tension is gradually increased to an extremely high value, the line moves from points *A* to points *B*.

As motivation of the assembly begins in the direction shown, the line of minimum conical effect rises from point *B* to point *C*, the line of maximum conical effect assuming a position on the pulley surfaces diametrically opposite.

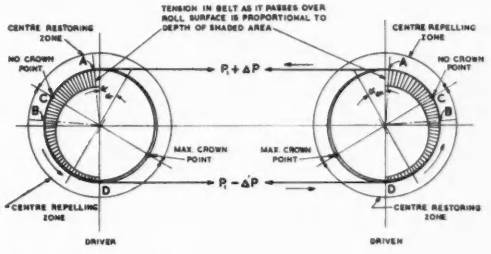



Fig. 5. **Behaviour of automatic self-centring roll when used for conveyor or transmission belt pulleys.**

The position of points *C* on the surface of the pulleys is variable and always lies somewhere between points *A* and *B*. Point *C* always represents one extremity of the diametrical line at which the centre-restoring zone of the pulleys at the surface begins or ends. Conversely, *C* also represents the points at which the centre-repelling zone begins or ends.

The shaded areas shown in each pulley, the inner boundaries of which are not accurately developed or shown for the forces being applied to the system, represent the rate at which the tension in the strip is reduced on the surface of the driving pulley as it is forwarded over this pulley by frictional contact, and the rate at which tension in the strip increases on the

surface of the driven pulley as it rotates this pulley by frictional contact.

Point *C* will always lie on or closely adjacent to the radius line on which the centre of gravity of the shaded area lies. If the position and shape of the shaded area changes because of a change in live load, then the positions of points *C* change correspondingly. The position of the centre restoring and repelling zones also changes in a corresponding manner as the position of points *C* changes.

In Fig. 5 the metal belt approach to the driving pulley under reasonably high tension always contacts the pulley in the centre restoring zone, where the crowning or conical effect is very low, being practically zero in actual practice. The conical effect decreases between points *A* and *C* and reaches zero at point *C* on the driving pulley. From *C* to *B* to *D*, the conical effect increases, but never reaches its maximum while the belt is in contact. Thus, the belt in its most highly stressed condition when in operation is in contact with the driving pulley where the conical effect is always the least possible. The conical effect is greatest where the belt is least stressed while in contact.

As the return strand of the belt approaches the driven pulley in its least stressed condition, it contacts the pulley at *D* in the centre-restoring zone, but not at the line of maximum convexity. As the stress in the belt gradually increases to a maximum at *A*, the conical effect from *D* to *B* to *C* becomes gradually less, reaching zero at point *C*. From *C* to *A* the conical effect increases slightly but remains very low.

## ADVERSE EFFECTS OF SPRING-LOADED MOUNTINGS

Compression spring mountings, unless preloaded to prevent deflection under the total normal pressure required in operating, are a detriment to the securing of good centring and aligning. Rolls or pulleys, with spring mountings at both journals in which the springs are free to expand or contract under a slight change in loading on either side of the pass line, always tilt the rolls with their planar action adversely when the edges of the strip or belt are not equidistant from this centre pass line.

The distance from one strip edge passing over a roll to its nearest spring mounting, if greater than the distance from the other edge to its nearest mounting, will, if the two mountings are under the same initial pressure, cause the strip edge farthest away to continue moving away and the other edge to move closer to the centre pass line.

When passing metal strip over rolls that are free to be tilted slightly on spring mountings, each edge of the strip tends to act as an intermediate lateral floating fulcrum of a lever, the roll being a lever of fixed length with a spring at each end. The two lateral floating fulcrums, being represented by the two strip edges, remain equidistant with respect to the two ends of the lever represented by the fixed length of the roll.

Spring mountings free to expand or contract for rolls in contact with metal in conveying, processing or belted systems should, therefore, never be utilized if their use can possibly be avoided for reason of their highly detrimental effect on tracking. If they must be used as shock absorbers or as take-ups, they should either be preloaded, so as to be inactive under normal operating strip tensions, or the mountings should be equipped with long sliding guide members to cause both ends of the rolls to move in unison exactly the same amount if possible and in the same direction.

Independently acting counterweights or compressed air and hydraulic cylinders replacing spring mountings on each end of the rolls, to apply pressure on moving strip, rotating coils, and the like, are as detrimental to tracking as spring mountings free to expand or contract.

## CONSTRUCTION OF AUTOMATIC SELF-CENTRING ROLLS

Split automatic self-centring rolls and pulleys can be constructed so that they are either unidirectional or reversible in their operation as far as centring and aligning is concerned.

For some specific applications, the unidirectional type is recommended, whereas for most applications the reversible type can be used to better advantage. In any case the roll or pulley must be split at the transverse centre line of the assembly as indicated in Figs. 4 and 5. Fig. 4 shows the simplest form and type of construction for an automatic self-centring roll that can be operated equally well in either direction, and can be made suitable for most applications.

Questions will arise as to the initial cost, maintenance and life of split rolls and pulleys as compared with conventional continuous-bodied units at present being used.

The initial cost of the rolls themselves may be somewhat higher, but the advantages to be gained should materially reduce the initial overall cost of the equipment required to do a particular job.

Maintenance of the split automatic self-centring rolls themselves should be less than for conventional rolls for two very important reasons; first, automatic centring and good tracking of strip-like material can be secured under far less strip tension than at present required, and second, the crowning or conical effect on rolls can never be totally destroyed by wear on automatic self-centring rolls while in operation.

The life of split automatic self-centring rolls should be greatly increased as compared with conventional continuous-bodied rolls for the reason that they require little if any regrinding of the roll surfaces to remain effectively operative during their life. The design can be such that the slight deflection in the roll surface required to centre and align strip-like material properly will create stresses and strains in the rolls and shafts that are no greater than those caused by the combined bending and shearing stresses and strains in the rotating shafts of conventional rolls immediately adjacent the roll body ends and shaft journals (usually the critical point of stress and strain in conventional rolls).

## APPLICATIONS OF SPLIT AUTOMATIC SELF-CENTRING ROLLS

Small diameter model automatic self-centring rolls have been operated at rotative speeds of 10,000 rpm without difficulty. A model belted system consisting of two 5-in. diameter centring pulleys and light gauge stainless steel belt, 0·005-in. thick, also a light gauge paper belt, were operated with the pulleys rotating at about 5,300 rpm with the belts travelling at 6,800 fpm. Excellent tracking was secured and the belts always returned to the centre pass line when forced off centre on either side.

Full-scale split rolls and pulleys of the self-centring type have been in operation in commercial processing lines for several months. The results reported are very good, indicating that the rolls and pulleys function in accordance with the experimental findings.

Several full-scale split automatic self-centring rolls are at present being constructed for various companies at Carnegie-Illinois Steel Corp.'s Johnstown works for use in experimental full-scale metal strip conveyors and metal strip processing lines.

The development and use of split automatic centring rolls is not limited to the iron and steel producing industry alone. Practically every industry where driven conveyor and idler rolls and pulleys are utilised for forwarding strip-like materials in a definite path should find economic advantages in the utilisation of automatic self-centring rolls.

# CLASSIFIED ABSTRACTS

*Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.*

## BALL AND ROLLER BEARINGS

### The Use of Roller Bearings in Sheet Mills

By W. KRÄMER. (From *Stahl und Eisen, Germany*, Vol. 70, No. 21, October 12, 1950, pp. 925-929, 10 illustrations.)

IF roller bearings were fitted in sheet mills, they would contribute to a saving in power, lubricant, and maintenance costs, permit finer adjustment of the rolling gap, and lead to greater bearing rigidity and longer life. These advantages would, in the long run, outweigh the disadvantages of higher initial costs and re-design of the mill stands. The roller bearings cannot be mounted directly on the roll necks because of the large diameter that would be required and the high service temperature to be expected. Instead, they must be mounted indirectly, i.e., on special brackets or in the housing, the necessary adjustment of height being effected by means of wedges, screws, or eccentrics. The roller bearings thus serve as bearings for heavy steel rollers which are fitted either on the outer race or on the same shaft, next to the roller bearing, and these rollers exert pressure on the neck of the roll. Various possible designs are shown and discussed in the article.

If the brackets are fitted with two guide rollers arranged side by side in the direction of rolling, the housing aperture will be large, and the housing itself must be very sturdy. The rear guide roller then takes the horizontal feed pressure as well as part of the rolling pressure and may, therefore, be larger in diameter than the front roller. However, a single guide roller may also be arranged in the vertical plane of the rolls, and two small auxiliary rollers may be used to take up the feed pressure. Due to the small area of contact between roll neck and guide roller, the roller bearings will run at rather low temperatures, probably below 200° C, even if not cooled specially. Oil mist lubrication is suggested, the oil mist being blown into the bearings, at 70 psi pressure, by compressed air, which also provides a cooling action. If roller bearings are to be used in a three-high mill, it is suggested that the centre roll be supported on orthodox sliding journals.

## FOUNDRY PRACTICE

### A Simple Test for Hot-shortness of Light Alloys

By A. TATUR. (From *Fonderie, France*, No. 59, November 1950, pp. 2245-2256, 19 illustrations.)

CERTAIN light alloys show a pronounced tendency to hot-shortness, and often crack during cooling in steel moulds or even sand moulds. Cracks, and even fracture, occur at high temperatures, when the casting has not yet developed sufficient strength to resist the high shrinkage stresses. In order to detect and compare the degree of hot-shortness of various alloys, several authors have devised tests, most of which, however, are too complicated for rapid production testing. The paper presents a new, star-shaped test mould made of steel, oxidised and slightly lubricated with thin oil, which permits the rapid and safe detection of hot-tearing tendencies as well as a quantitative comparison of these tendencies in different materials. Six round bars with discs of slightly larger cross-section at their ends are cast around a central hub, the lengths of the bars being unequal so that the contraction stresses are different in each of them. The longest bar will show the severest cracks, if not fractured altogether. If, for each of the six bars of the casting, complete fracture be taken as unity, severe cracking as 0·75, light cracks as 0·5, and cracks visible only under the microscope as 0·25, the total of the six figures thus obtained will characterise the hot-tearing tendencies of the casting, and the average total of a few test castings the corresponding qualities of the cast material. In order that casting conditions may be standardised, a sheet steel receptacle for the molten alloy, filled to a given line, is placed at the centre of the mould hub, and casting started by withdrawal of a stopper. When casting has to be started with a cold mould, the first two test castings are disregarded. By means of a few tests, and in a very short time, the most suitable casting temperature for a given alloy can thus easily be found and the effects of additions and grain-refining agents (titanium) investigated. A further valuable indication of the qualities of a material is obtained if the test piece is re-molten and re-cast, and the increase in hot-shortness with the number of re-casts observed.

## GEARING

### Advantages of Cold-Drawn Pinions

By E. H. RATHBONE. (From *Product Engineering, U.S.A.*, Vol. 21, No. 12, December, 1950, pp. 114-116, 3 illustrations.)

THERE are three methods of making small pinions, namely, by cutting the teeth, by extruding to the finished diameters and tooth forms, and by cold-drawing rods into finished pinion rod. If the metal has good cold-working properties, the last process produces pinions of the highest durability and load-carrying capacity, and to an accuracy equal to or better than cut teeth.

Whereas pinion rod can be extruded only in the softer non-ferrous metals, such as bronze and aluminium, cold-drawn pinion rods can be made of high carbon steel, stainless steel, nickel, silver, Monel, sterling silver, and any other metals which have good cold-working properties.

The proper design of tooth forms best adapted to cold-drawing has not received the attention it deserves. While it is possible to produce almost any tooth form desired, some shapes have better "draw balance" than others. Experience has shown that almost all gears and pinions of involute form can be produced with slight modifications to adapt them to the drawing process.

The advantages of cold-drawn pinions over cut pinions can be summarised as follows :—
(1) For large-quantity production, cold-drawn pinions are cheaper ; (2) cold-drawn pinions are stronger and more wear-resistant ; (3) greater uniformity of structure because a poor material cannot be cold-drawn ; (4) greater uniformity of size and shape, because the process of cold-drawing is continuous. One coil of stock converted into pinions represents a large quantity of finished parts, hence inspection costs can be reduced to a minimum ; (5) greater versatility. The process is adaptable to all kinds of toothed wheels including rachets, sectors, cam-shaped gears and various types of non-circular gears. Some of these non-circular types,

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such as elliptical and cam gears, are usually costly to produce, since they cannot always be manufactured by generating methods ; (6) low tool write-off. The cost of tooling for producing cold-drawn pinion rod is generally much lower than that of the tools used in gear-generating equipment.

### A New Machine for Generating Bevel and Spur Gears

By W. KRUMME. (From *Werkstattstechnik und Maschinenbau, Germany*, Vol. 40, No. 12, December 1950, pp. 413-415, 11 illustrations.)

WHILST the design of gear cutting machines has a present-day tendency towards single-purpose machines and single-purpose tools, a new machine has been developed which aims rather at versatility, as it serves, with some modifications, for cutting spur gears with straight or helical teeth as well as bevel gears with straight teeth.

Two disc cutters with inserted blades, similar to those used on some bevel gear cutting machines, serve as generating tools. The same blades can be used both for bevel and spur gears. A set of blades can be used for several pitches, for instance, from module 3 to 6 (diametral pitch 8 to 4), and a set for, e.g., a 20-degree pressure angle can also be used for producing gears with a different pressure angle, if special blades for such angles are not available. By means of a special fixture, the cutter blades can be ground on any plain grinding machine.

Gears up to module 6 (diametral pitch 4) can be cut from solid blanks, and the time per tooth is 5 to 40 seconds, according to material and pitch. It is claimed that between 10,000 and 40,000 teeth can be cut without regrinding the blades. Unproductive time is practically eliminated by a twin arrangement of the workheads so that one half of the aggregate can be loaded while the other is working.

The machine is based on unit construction. As the generating movement is imparted to the work, the same tool carriers and cutters can be alternatively combined with workheads for bevel and spur gears. This uniformity simplifies the provision of spare parts in works where there are several of these machines, and affords smaller workshops the opportunity of changing-over a single machine from bevel to spur gear production.

## METALLURGICAL ENGINEERING

### Evaluating Carbon Plate Steels by the Keyhole Charpy Impact Test

By R. W. VANDERBECK. (From *The Welding Journal Research Supplement, U.S.A.*, Vol. 30, No. 1, January, 1951, pp. 59s-64s, 8 illustrations.)

KEYHOLE-notched Charpy impact tests were performed on ½, ¾, 1- and 1½-in. hot-rolled plates from production heats of carbon steel. Various de-oxidation practices were employed, and the heats differed in carbon and manganese contents.

As the testing temperature was lowered, a sharp transition was obtained from tough (absorbing a minimum of about 20 ft-lb) to brittle (absorbing about 5 ft-lb) behaviour. This transition took place over a range of temperatures. In this transition range, both relatively high and low impact values were obtained with few intermediate values. The absence of values at intermediate energy levels was clearly demonstrated by frequency distribution plots of the number of values occurring at different energy levels. A minimum point in the frequency curve is believed to indicate the energy level at which the energy is changing most rapidly with temperature.

The energy level where the fewest impact values occur seems to depend mainly upon the carbon content of the steel, and is higher for steels of lower carbon contents. Thus, for 0·23 and 0·16 per cent carbon steels, these energy levels are, respectively, about 11 and 16 ft-lb.

The energy transition observed for the keyhole-notched Charpy specimens, as indicated by a scattering of energy values, is associated with the change from a fibrous to a granular fracture of a very small area just below the notch. This transition has been called the "ductility transition" and represents the transition from relatively tough to brittle behaviour. However, a completely fibrous fracture may not be obtained until the testing temperature is increased some 100° F above the ductility transition. The ductility transition, therefore, is quite different from the well-known fracture transition (based on change in overall fracture appearance) which has been obtained with many other types of notched specimens.

Transition temperatures were selected at the middle of the transition range at the energy level where fewest values occurred. Using this method of evaluation, a summary of the results for full-size, hot-rolled plates shows that low transition temperatures are favoured by :—

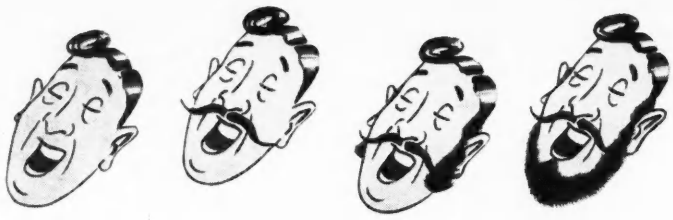
(1) Deoxidation with both silicon and aluminium,
(2) Lower carbon and higher manganese contents,
(3) Lighter-gauge plates. The lower transition temperature of thin plate is associated with its finer ferrite grain size, which is attributable to a lower finishing temperature and a faster cooling rate.

## SCIENTIFIC INSTRUMENTS

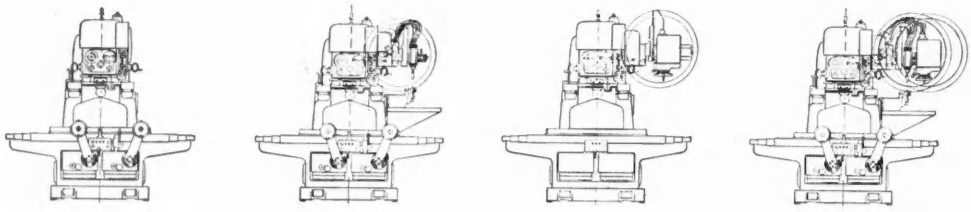
### On the Application of Electron Diffraction in Research Work.

By L. WEGMANN. (From *Hutnické Listy, Czechoslovakia*, Vol. 5, No. 10, October, 1950, pp. 397-406, 39 illustrations.)

THE basic laws of electron diffraction and the possibilities of applying these phenomena to practical research work are discussed. Since electron diffraction follows the same laws as do X-rays, it is possible to investigate the shape of crystals lattices by methods applying electron diffraction, thus providing a convenient research tool for a number of problems which are difficult to invstigate by means of X-rays. Electron diffraction is particularly suitable for the investigation of very thin layers in chemical microanalysis, in optical work where thin layers of a thickness of ¼ or ½ wavelength are involved, and also for the investigation of the surface condition and finish of metallic and non-metallic specimens. A further interesting field of application is the investigation of friction and lubrication problems. The lubricant film does not show an amorphous structure, but, contrary to expectation, shows a typical crystalline structure, the shape and distribution of the crystals varying within very wide limits according to the friction surfaces and the lubricant concerned. A comprehensive picture of a given friction problem can be obtained very quickly by applying a diffractograph in many cases where the investigation of all possibilities by actual friction tests would not be practicable. A diffractograph of Swiss origin is described, and comparative pictures obtained from the same samples by an electron microscope and a diffractograph are given. Professor Trillat has designed a special attachment for this diffractograph which permits observation of the changes in surface quality of a specimen during the heat-treatment process. Prof. Courtel has designed a polishing device which can be fitted inside the diffractograph and permits observation of the changes in the surface during the polishing process. He has thus developed a polishing process for car pistons which eliminates the necessity of running-in.



*something to sing about* — **Four variations . . .**



## . . . of one machine!

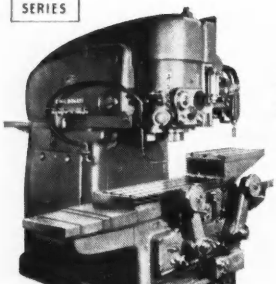
**1.** This is the basic machine, shown in the 16″ series in the diagram above and in the 28″ series below. It is a general purpose milling machine; hand and power feeds are fitted to table and cross-slide and hand feed to vertical spindle carrier as standard. Power feed is available for the latter when required.

**2.** Here is the same machine with die-sinking equipment with automatic depth control which provides sensitive automatic tracing in a vertical plane either from templates or a master shape. It may of course, be used for either general purpose milling or automatic controlled die-sinking. This variation applies to both 16″ and 28″ series.

**3.** Here, the basic Milling Machine is equipped with an automatic hydraulic 360° profiling mechanism for profiling type work only. With this style, table and cross slide movements are automatically controlled entirely by the profiling mechanism. Again this variation applies to both 16″ and 28″ series.

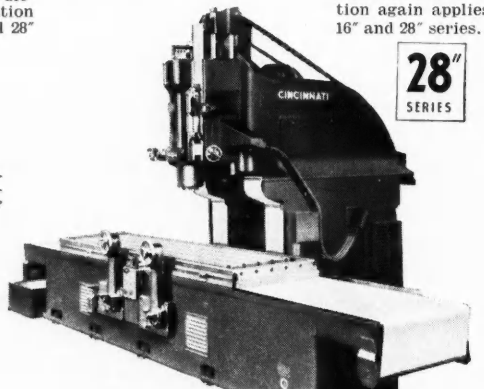
**4.** Here the diagram shows the basic machine equipped with both variations described in 2 and 3 thus providing complete in one machine a general purpose milling machine, automatic die-sinking machine and automatic profiling machine. This double variation again applies to both 16″ and 28″ series.

**16″ SERIES**



*Full details and specifications of these multi-purpose machines are available on request.*

**28″ SERIES**




## VERTICAL HYDRO-TEL MILLING MACHINES

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*Sales Representatives for the British Isles.* CHARLES CHURCHILL & CO. LTD., COVENTRY RD., SOUTH YARDLEY, BIRMINGHAM, 25

# NEWS OF THE MONTH

## PERSONAL

**Mr. H. P. Barker,** managing director of Parkinson & Cowan Ltd., has been appointed part-time member of the British Transport Commission.

**Mr. F. J. Bates, M.B.E.,** Works Director of B.S.A. Tools Ltd., and Index Automatic Machine Co. Ltd., and a director of Cardiff Foundry & Engineering Co. (1947) Ltd., and Leo. C. Steinle Ltd., has recently retired from an active directorship after being with the B.S.A. Tools Group for forty-two years, but his services will remain available in a consultative capacity.

**Mr. C. A. Clench, M.I.Mech.E.,** has been appointed chief generation engineer (construction) of the London Division of the British Electricity Authority, in succession to **Mr. A. Pollitt, M.I.Mech.E.,** who has become deputy divisional controller.

**Mr. L. H. Cooper** has been appointed chairman, and **Mr. L. K. Brindley,** managing director of The Mond Nickel Company Ltd. **Mr. G. Archer** and **Mr. A. Parker** continue as directors, and **Mr. I. A. Bailey, Dr. L. B. Pfeil** and **Dr. A. G. Ramsay** have been appointed directors of the Company.

**Mr. H. Fletcher,** director and general manager of Danks of Netherton Ltd., Netherton, Dudley, has been elected chairman of the Company.

**Mr. Stanley Hollands** has been appointed an executive director and director-in-charge of the technical services of A.C.V. Sales Ltd., Southall, Middlesex.

**Mr. W. Kelsey** has been appointed general manager of the steel works of Peter Stubs Ltd., Rotherham.

**Mr. J. Muil, A.M.I.E.E.,** who has been with the Technical and Scientific Register of the Ministry of Labour has been appointed Registrar and Secretary of the Professional Engineers Appointments Bureau, 9, Victoria Street, Westminster, S.W.1., in succession to **Mr. H. J. Nichols, C.I.E., D.Sc., M.I.C.E., A.M.I.Mech.E.,** who has resigned.

**Mr. W. E. A. Redfearn,** a special director of English Steel Corporation Ltd., River Don Works, Sheffield, 9, has been elected chairman of the Alloy Steels Association, in succession to the late **Major Guy S. Newton.**

**Mr. C. A. Reed,** works manager of the Skinningrove Iron Co. Ltd., has been appointed a director of the Company.

The Board of **Powell Duffryn Ltd.,** announce the appointment on the 1st February, 1951, of **Sir Henry Wilson Smith, K.C.B., K.B.E., Mr. Alfred Read, M.B.E., Mr. Miles Belfrage Reid, M.B.E., M.C., J.P.,** and **Mr. Thomas Stuart Overy** as additional directors of the Company. Mr. Alfred Read will retain the office of Secretary to the Company.

**Mr. J. S. Tritton** has been elected President and **Mr. K. J. Cook, O.B.E.,** and **Mr. R. F. Harvey, M.B.E.,** vice-presidents of the Institution of Locomotive Engineers, 28 Victoria Street, London, S.W.1.

## BUSINESS NOTES

**The Triplex Safety Glass Co. Ltd.** has acquired the engineering firms Stern & Bell Ltd., Birmingham, and Weldall and Assembly Ltd., Stourbridge.

**The Rapid Magnetic Machines Ltd.,** Lombard Street, Birmingham 12, manufacturers of magnetic lifting equipment and pioneers of magnetic separation, has recently celebrated its Golden Jubilee with a large gathering of employees, their wives and friends.

**Fibreglass Ltd.** have introduced an interesting new development, Fibreglass "S.I." Board, where a mat of unbonded insulation wool is dipped in a binder based on a Bakelite phenolic resin and compressed. Pressure is maintained while the board passes through an oven where the resin is cured. The result is a board weighing 8-9 lb to the cubic foot which can be used for structural insulation, being supported at 3 ft centres. It is claimed that this board has higher insulating properties than any other insulating board.

**Murex Ltd., Rainham, Essex** have recently initiated the production of zirconium metal on a commercial scale. Previously only very limited supplies were available in England and even now full production has not yet been attained.

Sheets down to 0·005 in. in thickness, 6-7 in. in width and 2-3 ft in length are now being made, and it is expected that sheets up to 12-15 in. in width will be available in the course of the next few months. Rods down to 2 mm diameter can be supplied and drawn zirconium wire may also shortly be available.

**The Hymatic Engineering Co. Ltd.,** of Redditch, Worcs., has recently introduced the first of a series of special test rigs to assist in the maintenance of Hymatic airborne equipment. Using the new rig, two inspectors can work side by side testing either pressure regulating valves or oil and water traps.

The rig consists of an enclosed metal framework, measuring 4 ft 2 in. long by 2 ft 2¼ in. wide by 4 ft 2¼ in. high, which houses two single-cylinder, two-stage, stepped-piston, air-cooled compressors driven by vee-belts from a single electric motor. The compressors are connected by pipe lines to the equipment's own pressure regulating valves and oil and water traps and thence to duplicate 300 cu. in. capacity air receiving bottles. Maximum working pressure is 600 psi.

The top of the framework is covered in to form a work bench upon which two adaptors and dual sets of controls are conveniently mounted on either side of a central immersion tank used for the testing of Hymatic oil and water traps. Line and bottle pressure gauges together with the two connecting pipes are located in the back instrument panel.

Orders for these test rigs have already been received from Indo-China, Switzerland and Sweden.

**Protolite Ltd.,** Central House, Upper Woburn Place, London, W.C.1 reports that on a well-known make of Capstan Lathe, steel forgings are held during the machining operations in a Collet equipped with Prolite pads and the life per set has so far been increased fifty fold. This figure, it is claimed, will be greatly exceeded, as up to the present there is no sign of wear on the Prolite Pads.

## THE SWISS INDUSTRIES FAIR 1950

The goods offered by Swiss industry are probably never seen anywhere else in such compact and yet all-embracing display as at the Swiss Industries Fair in Basle. At this industrial Fair, which has never ceased to emphasize its export character, the number of exhibitors showing technical products has continued to increase, and this will be the case again for the 34th Fair, from the 15th to the 25th April, 1950.

The Swiss machinery manufacturers will be in a position to present a display capable of satisfying the most exacting demands with regard to the use of genuine materials, harmony of shape and precision of execution. The metal and wood working machinery and also the textile machinery group will again be united in a homogeneous and uniform display. Constructional machinery will also once again be a prominent feature of the building trade display, and machinery for the graphic, paper and foodstuffs industries will be concentrated in a special group worthy of attention. No less interest will be aroused by the special group comprising industrial accessories, tools, precision mechanics, measuring instru-


*Protected against gland wear & corrosion . . .*

A 32-page booklet covering the process will be sent to responsible enquirers.

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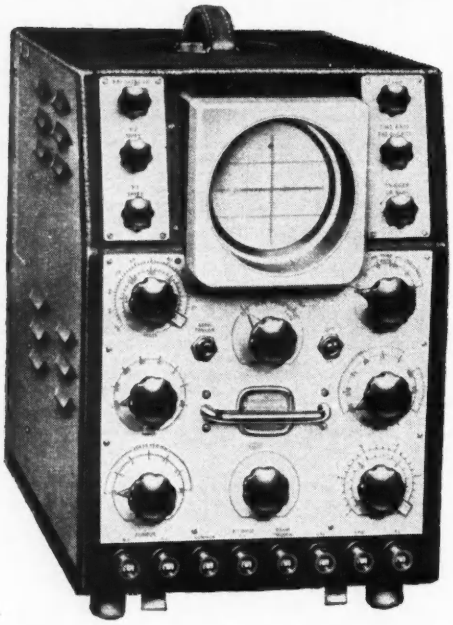

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The Double Beam Tube presents two simultaneous independent traces over the full diameter of a 90 mm. screen, and provision is made for the measurement of both input voltage and time upon the calibrated dials of the instrument. The Oscillograph is particularly suitable for obtaining permanent photographic records using the Cossor Model 1428 Camera for which a Motor Drive Attachment Model 1429 is available.

Widely different industries are daily finding new uses for the COSSOR Double Beam Oscillograph. Sometimes it provides the answer to an industrial problem of long standing. The tracing and measurement of noise, strain and vibration are typical everyday applications of this versatile instrument which is already helping engineers in industries as far apart as brewing and the manufacture of jet engines. Call on our technical advisory staff if you have a problem. They will quickly let you know whether the Oscillograph can help you.

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ments, surgical instruments, optical and photographic goods. The Swiss electrical industry will also be present with a choice display representing the many processes of production involved. Mention should also be made of the motor lorry exhibit, as well as the groups for gas, water and heating.

Finally, the Swiss watchmaking industry, which may claim for itself the reputation of manufacturing precision-made goods of the finest material and artistic perfection, will be represented with its own special exhibit, for the 20th time.

Swiss Legations, Consulates and Chambers of Commerce are only too willing to supply information as to making the most favourable arrangements for a visit to the Fair in Basle.

### LIEGE INTERNATIONAL FAIR

The 3rd Liege International Fair which will be held at Liege from April 21 to May 6, will provide an opportunity for those responsible for the practical application of the Schuman Plan to compare different types of material, and make the choice best adapted to their individual needs.

A number of European and American manufacturers of mining equipment are to be represented in a remarkable collective exhibit that will show material for mining in all its branches, a special feature being made of all known devices for propping and shoring.

There will also be on view installations for blast and smelting furnaces, for the processing of steel at every stage and, in general, for the manipulation of raw, semi-processed or machined products intended for constructional or mechanical engineering.

Industrialists who find they are obliged to adopt modern production techniques, will thus have an unrivalled opportunity of examining a wide range of machinery and material of the types in which they are interested.

### ERECTION OF THE "SKYLON" FOR THE FESTIVAL OF BRITAIN

Preparations are now in hand for the erection of "Skylon"—the symbolic emblem for the Festival of Britain exhibition site. The "Skylon," the supply and construction of which is the responsibility of **British Insulated Callender's Construction Co. Ltd.,** will consist of a 250-feet long elliptical beam supported by a system of pylons, steel cables and anchorages which hold it vertically suspended 40 feet above the ground. At night, it will be illuminated internally, the light being graded from a low intensity of amber at the base to an intense white at the top.

Each pylon is 70 ft long, tapers in width from 1 ft 8 in. at either end to a maximum of 2 ft 3½ in. along the centre 46-ft length, and weighs 6½ tons. The pylons are of triangular cross-section and consist of a welded steel section framework which is covered with ¼-in. mild-steel plates. Triangular cross-section has been employed as this permits a pleasing appearance and an economical robust construction (each pylon will have to resist a maximum compression load of 200 tons). The pylons are painted black to make them as inconspicuous as possible by night, thus giving the impression that the main beacon structure is floating in space.

### COAL PRODUCTIVITY TEAM FOR AMERICA

Productivity in the Coal Industry is to be studied by a British Team that left for America on January 31st. The tour, organised by the Anglo-American Council on Productivity, with the technical assistance of E.C.A., is of particular interest in view of the critical position in the coal industry, and the itinerary has been specially planned to include a dozen American bituminous coalfields where conditions are comparable to those prevailing in Britain. The sixteen members, who have been nominated jointly by the National Coal Board and the unions concerned, have been drawn from all levels in the industry. The Team leader is Mr. E. L. Chiverton, production director and vice-chairman of the South-Eastern division, and the secretary is Mr. G. Essame, O.B.E. Two divisional chief engineers, three supervisory mining engineers, an overman, a deputy and a shotfirer, and six representatives of the main grades of workers complete the number.

### TRAINING FOR SUPERVISION IN INDUSTRY

The second Specialist Productivity Team to study methods of training for industry in the U.S. sailed for America under the auspices of the Anglo-American Council on Productivity. The first Team, which is now in America, has the task of studying methods of training within industry and for industry in technical colleges at the level of the operative. The second Team will give its attention to training for supervisory duties up to but not including higher management. It will investigate methods used and the nature and extent of facilities provided both inside and outside industry for the development of the needful qualifications. The enquiry covers the provision of opportunities for potential supervisors and the method of their selection.

The Team, will be led by Mr. J. R. Armstrong, Chief Education Officer of Joseph Lucas Ltd., Birmingham. The tour in America will last six weeks, and the itinerary will include visits to a number of industrial plants of varying size, and to technical institutes. Conferences will also be held with representatives of industrial and educational organisations.

### NEW TIN-SAVING THICKNESS GAUGE

A new eletronic thickness gauge for the quick, accurate, economical, non-destructive gauging of tin coatings on ferrous stock has been developed by the Research and Control Instruments Division of North American Philips Company, Mt. Vernon, N.Y., in co-operation with one of America's largest steel and tin plate producers.

The unit conserves critical tin by making possible the maintenance of continuous coatings of satisfactory characteristics. It does this without wastage, as the test sheet may be used in the ultimate product. It permits close quality control more speedily and more accurately than conventional chemical methods and with considerable savings in time.

Thicknesses may be checked on one side of a sheet at a time, or on both sides simultaneously. A point check can be determined in approximately 30 seconds. Thicknesses from 10 to 120 micro-inches can be determined to within about 2 per cent accuracy, or 1 micro-inch. Thickness determination can be made at various

# Classified Advertisements.

*The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.*

## SITUATIONS VACANT

**A.M.I.Mech.E., A.M.Brit.I.R.E., City & Guilds, etc., on "NO PASS — NO FEE" Terms.** Over 95% successes. For details of Exams. and courses in all branches of Engineering, Building, etc., write for 176 page Handbook—FREE.—**B.I.E.T.** (Dept. 96), 17 Stratford Place, London, W.1.

## MACHINERY, ETC., FOR SALE

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## MISCELLANEOUS

**CLEANING,** sterilising and repairing Service for Industrial Gloves, Aprons and Overalls, etc.—quick, reliable and well-recommended—**Burlington Gloves Ltd.,** Treforest Trading Estate, Glam. 'Phone: Taffs Well 152.

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positions along a sheet. Continuing process control can be maintained to ensure very close tolerances on thickness over any desired areas.

In this electronic apparatus, collimated X-radiation from a high-intensity X-ray tube is directed onto the plated test sheet. The emergent radiation is accurately measured by a Geiger-Counter, which operates suitable electro-mechanical printed tape registers.

## TWO PUBLIC DISCUSSION MEETINGS

The Midland Industrial Designers Association have arranged two public Discussion Meetings which will be held during the spring. Admission is free, but tickets must be obtained in advance from the Secretary of MIDA, Mr. D. H. Woodfull, M.S.I.A., 47 Farnol Road, Yardley, Birmingham 26.

On February 16, Mr. James Holland, F.S.I.A., A.R.C.A., Joint Chief Designer for the Festival of Britain, will speak on **The Festival of Britain.** Sir Hugh Chance, Chairman of Messrs. Chance Bros. Ltd., will be in the chair.

On March 9, at a meeting held jointly with the Birmingham Publicity Club, Mr. E. C. Mackenzie, Managing Director, Messrs. Sir William Crawford & Partners, Ltd., will speak on **Industrial Design and Publicity.** The chair will be taken by Mr. Frank Johnson, Managing Director of Birmingham Gazette Ltd

Both meetings will be held at 7.15 p.m. in the Imperial Hotel, Temple Street, Birmingham.

## 1951 B.I.F. CATALOGUES WILL AID FOREIGN BUYERS

First consignments of the British Industries Fair advance catalogues will this week be flown overseas to assist foreign buyers in planning their visits to the 1951 Fair, which will run simultaneously at Earls Court and Olympia in London and at Castle Bromwich, Birmingham, from April 30 to May 11.

Within the next fortnight a further 15,000 copies of the catalogues, each volume of which runs to more than 1,000 pages and weighs some 2 lb, will be dispatched to 180 United Kingdom government posts in 63 countries for distribution to prospective visitors to the Fair. As last year, there will be a special distribution for the North American markets.

The B.I.F. catalogues are valued not only as an aid to pre-planning the buyer's itinerary at the Fair but as books of reference for British industry. Overseas demand is far in excess of the number it is possible to print, and this year five different printers had to combine their resources so that the advance editions of the London issue could be ready in time.

## HEAT TREATMENT AND PROPERTIES OF IRON AND STEEL

A new circular just released by the National Bureau of Standards, presents basic theoretical and practical principles involved in the heat treatment of ferrous metals. This circular has been prepared in simplified form principally to give an understanding of heat treatment to those unacquainted with the subject.

The effects of various treatments on the structural and mechanical properties of iron and steel are thoroughly discussed although many theoretical aspects and technical details have been omitted for the sake of simplicity. Subjects presented include properties of iron, alloys of iron and carbon, decomposition of austenite, heat treatment of steels, hardenability, heat treatment of cast iron, nomenclature of steels, recommended heat treatments, and properties and uses of steels. A list of selected references is also given, and a large number of graphs, tables, and photographs illustrate the text.

Circular 495, **Heat Treatment and Properties of Iron and Steel,** by Samuel J. Rosenberg and Thomas G. Digges, 33 pages, 25 cents a copy, is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Remittances from foreign countries should be in United States exchange and should include an additional sum of one-third the publication price to cover mailing costs.

## BOOKS RECEIVED

**Modern Gas Turbines.** With special Reference to Stationary, Aircraft, Locomotive and Marine Types, and to the Supercharging of Internal Combustion Engines. Second Edition, Revised. By Arthur W. Judge. 388 pp., 248 illustrations. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. PRICE: 32/- net.

**Air Compressors.** Control and Installation. By P. C. Bevis. 192 pp., 87 illustrations. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. PRICE: 20/- net.

## BRITISH STANDARDS

(*Copies of British Standards may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.*1)

**Mercury Arc Rectifier Equipments. (B.S. 1698 : 1950).** As the culmination of many years of research and discussion the British Standards Institution has recently published a British Standard for mercury arc rectifier equipments. This work has been subject to some delay due to parallel discussions which have been taking place in a Technical Committee of the International Electrotechnical Commission. The recommendations of the I.E.C. have been taken into account in preparing this British Standard. It applies to mercury arc rectifier equipments comprising half-wave rectifiers of any type having mercury pool cathodes, rated at 50 kW and above, having not less than 6 phases, for d.c. voltages not exceeding 4,000, and for service in non-explosive atmospheres.

The standard includes sections on definitions, rating classes and overloads, rectifier and associated auxiliaries, main and interphase transformers and performance and high-voltage tests applying thereto. Efficiency, power factor and regulation are also dealt with and the appendices include service conditions, reduction of limits of temperature rise for ambient or coolant temperatures higher than standard, calculation of r.m.s. currents in transformers, method of calculating inherent regulation, and information which is required to be given with enquiries for these equipments. Price 5/-.

**X-Ray Diffraction Powder Cameras (B.S. 1693 : 1950)** deals with two sizes of X-ray diffraction powder cameras :—

(a) Cameras having a nominal diameter of 9 centimetres, which are intended for use at room temperatures where the film is mounted by the Van Arkel or by the Bradley-Jay method.
(b) Cameras having a nominal diameter of 19 centimetres, which applies to cameras with fixed or removable film holder, in which the type is mounted on, or as a fibre of small diameter with provision for rotation or oscillation.

It sets out full details of general construction, dimensions, covers, specimen rotation and camera mounting and includes clauses on mechanical assembly and testing.

The publication of this standard should facilitate the comparison of films taken in different laboratories and should, in addition, be of use to manufacturers of associated apparatus, such as microphotometers and measuring instruments. Price 2/-.

**The Assessment of Surface Texture (centre-line-average height method) (B.S. 1134 : 1950)** refers to the measurement of the irregularities of metal surfaces machine-finished by various methods. Although relating primarily to these surfaces the principles may be usefully extended to the wider field of surfaces produced by other methods. The subject matter covers terminology, the instruments and methods to be employed in assessing British Standard index numbers for surface texture, preferred limits for the grading of surface texture by means of index numbers and the symbols to be employed in stating surface texture requirements on drawings.

There are appendices which supplement and explain some of the reasons for the recommendations made in the body of the Standard; these contain useful notes indicated by the titles: Remarks on surface profiles; The determination of C.L.A. index numbers; Notes on the direction of measurement; Notes on instrumentation; Note on the measurement of longer sampling lengths; The analysis of surface texture; Choice of sampling lengths; and, finally, Alternative assessment of surface textures.

A number of diagrams are shown illustrative of various types of surface and the whole constitutes a useful addition to the literature on the subject as it brings together much that has hitherto


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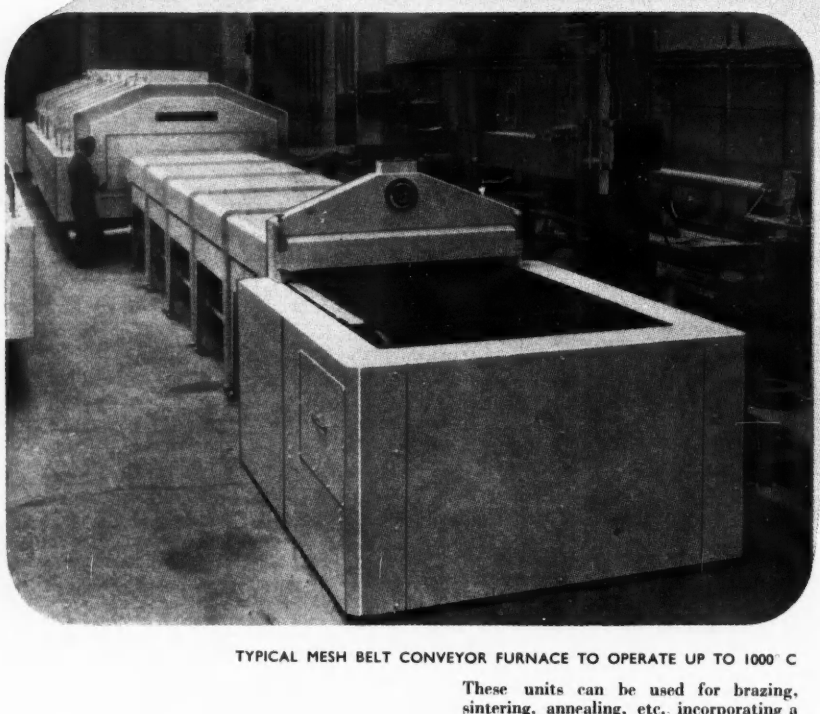

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These units can be used for brazing, sintering, annealing, etc., incorporating a controlled atmosphere if required.

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been scattered throughout various publications. The latest available information, hitherto unpublished, on methods of measurement is also given. Price 6/-.

**Dimensions of Unscreened Camshaft Speed Magnetos. (B.S. 1644 : 1950).** This British Standard forms one of a series relating to magnetos, dynamos and similar units for internal combustion engines.

It deals only with the dimensions of unscreened, camshaft-speed magnetos (combined with distributor head) having shank and spigot mountings. The dimensions included are those necessary to ensure interchangeability. The figures included are of typical magnetos and do not purport to represent standard designs or methods of locking the distributor head in position. Price 2/6.

**Higher Tensile Steel Chain (Electrically Welded) (B.S. 1663 : 1950)** constitutes a further publication in the series of British Standards for chains of varying materials and capacities, and provides for steel chain, electrically welded, having a higher minimum tensile strength and a greater minimum absorption factor than that covered by B.S. 590—"Mild steel electrically welded chain."

In addition to short link chain, the standard provides for pitched or calibrated load chain for use with pocketed sheaves, and the range of sizes covered (in terms of the diameter of bar from which the chain is made) is from ¼ in. to 2 in.

Specifications of quality of material, heat treatment, dimensions and tolerances of bar and links, and workmanship are included. The requirements of breaking strength and elongation are given, and the requirements of the testing machine are fully described. Recommended safe working loads are also specified. Price 2/6.

## MEASUREMENT OF DETONATION INTENSITY IN I.C. ENGINES

(*Concluded from page* 55)

timing varying with the compression ratio. This effect also depends on the type of fuel tested, and comparative curves may be obtained by plotting the detonation intensity against ignition advance for various fuels.

Measurements of the influence of mixture strength on detonation intensity at two different temperatures are shown in Fig. 12. With a 20 per cent rich mixture, the detonation intensity of fuel *B* is about the same for 50° and 150° C mixture temperatures, but with the chemically correct mixture the intensity at 150° C is approximately double the value at 50° C. The effect also varies with the nature of the fuel, as indicated by the dotted curve for another fuel *A*, which shows a less marked variation.

The difference in octane ratings obtained by the Motor method and by the Research method has been suggested as a basis for assessing the influence of mixture temperature on the detonating tendency of the fuel, particularly in relation to aircraft engines, in which the charging temperature increases with the charging pressure*. By means of intensity curves such as those of Figs. 7, 10, 11 and 12, the effect of mixture temperature can be investigated. It would, however, seem preferable to obtain such measurements from an aircraft engine cylinder, with tests covering the range of detonation intensities which are allowable in practical running.

The detonation meter equipment has also been used by the author for measurements of the ionisation current between two electrodes arranged in the combustion chamber, and preliminary tests gave promising results. The intensity curves obtained were much steeper, however, than those of other investigators†, since only the detonation wave was measured.

The method described in this article has been chiefly applied to determine the detonation properties of fuels in the lower intensity ranges, both on CFR engines and commercial engines. Further investigations may possibly give results leading to suggestions for the modification of the procedure employed for octane rating, so as to ensure better agreement with the detonation properties of fuels under practical running conditions.‡

*Nat. Petroleum News, Vol. 32, 1940, p. R.344.

†See : *K. Schnauffer*, Z.VDI., Vol. 75, 1931, p. 455, and VDI.-Sonderheft Dieselmaschinen, Part V, 1932, p. 127 ; *R. Schütz*, ATZ., 1939 ; and *R. Vichnievsky*, Trans. Faraday Soc., Vol. 42, 1946, p. 286.

‡The original paper includes a Bibliography with 43 references.


# CHANGE WHEEL GEARING

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Reprints of the article "Change Wheel Gearing," by O. Lichtwitz, M.I.Mech.E., are now available. Originally published in this journal in six instalments from January to June, 1950, the article has met with considerable interest among our readers. We have, therefore, decided to reprint it as a ready-reference work for all those concerned with change wheel gearing problems.

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Indexing when cutting multiple threads in a lathe introduces additional demands on the gear arrangement, and these problems are also dealt with.

The concluding chapter is devoted to the gearing of machine tools and contains ready-for-use tables for screw cutting, including metric and worm threads, which are often found to be troublesome.

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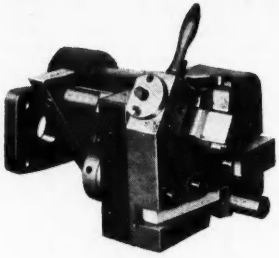

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